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9239-1, Session 1

Monitoring land surface with time series of satellite data: outliers, cloud cover and gap-filling *(Invited Paper)*

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Observations from space of the land surface are hampered by clouds at shorter wavelength and affected by water in the atmosphere in the microwave range. Both polar orbiting and geostationary satellites have a revisit frequency high enough to allow for some redundancy relative to the processes being observed, so that time series where a fraction of observations are removed and the resulting gaps filled are still very useful to monitor land surface processes. Three examples illustrate this concept in different spectral regions: VNIR and observation of vegetation, TIR and observations of land surface temperature and 37 GHz and observations of water-saturated soil.

The Harmonic ANalysis of Time Series (HANTS) algorithm has been widely used to reconstruct time series of Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), Land Surface Temperature (LST) as well as the polarization difference brightness temperature (PDBT) during the past 20 years to remove random noise or eliminate cloud/snow contamination. New or significantly improved algorithms have been developed and evaluated against ground measurements. Variables retrieved include land surface properties, rain rate, aerosol optical depth, water vapour, snow cover and water equivalent, soil moisture and lake level.

The Fast Fourier transform (FFT) and HANTS have been developed and applied to time series of satellite observations, e.g. NDVI and Land Surface Temperature, to study vegetation phenology and land surface climate (Alfieri et al. 2013; Jia et al. 2011; Julien et al. 2006; Menenti et al. 1993; Menenti et al. 2010; Moody; Johnson 2001; Roerink et al. 2000; Roerink et al. 2003; Verhoef 1996). Different from the FFT using all observations regardless of quality, the HANTS identifies and removes outliers in data samples.

A global study of the accuracy of HANTS in the reconstruction of NDVI time series has been completed. The overall reconstruction error was divided into gaps related error and fitting method related error. Firstly, ten annual NDVI time series for a pixel were used to extract reference series and gap conditions. Then the gaps and fitting method related errors were quantified independently. The results suggest that the gaps related error for most of the high latitude forest area (between 50N and 70N) was rather significant (the mean Root Mean Squared Deviation (RMSD) reached to 0.15).

A three year time series (2008 – 2010) of gap-free daily and hourly land surface temperature and actual evaporation derived from geostationary data collected by the FY-2D satellite was reconstructed for a large area including the Qinghai – Tibet Plateau and the surrounding river basins. Hourly LST observations, estimated from radiometric data acquired by the Single channel Visible and Infrared Spin Scan Radiometer (S-VISSR) sensor onboard the Fengyun-2C (FY-2C) Chinese geostationary satellite have been used to constructs a gap- and

cloud-free data set which covers the whole Tibetan Plateau from 2008 through 2010 with a 5?5Km spatial resolution. Multi-channel Singular Spectrum Analysis (M-SSA), an advanced methodology for time series analysis, has been utilized to reconstruct LST time series.

Due to the revisit frequency and swath width of microwave radiometers on polar orbiting satellites, time series of passive microwave data will have gaps of 3-5 days. To make a consistent daily time series, we need some statistical methods, such as a moving window filter, to fill these observation gaps. In addition, the effects of rain drops on microwave ground surface observations at 37GHz are not negligible. Geo-location and resampling introduce errors in the conversion from swath brightness temperature to the gridded data. Radiometric noise, such as the reference warm-up, also has an additional and unpredictable impact on observed BT. Erroneous observations need therefore to be identified and removed. In this case, we applied the Harmonic ANalysis of Time Series algorithm (HANTS) (Menenti et al. 1993; Roerink et al. 2000; Verhoef 1996) to fill gaps and remove noisy samples.

9239-2, Session 1

Passive microwave response to vegetation and soil moisture on agricultural fields

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Background

The SMAPVEX12 (Soil Moisture Active/Passive Validation Experiment 2012) field campaign took place in Manitoba, Canada during the summer of 2012. The goal of the experiment was to validate and test soil moisture models for NASA's planned SMAP (Soil Moisture Active/Passive) satellite over an extended period of time with varying soil moisture and vegetation conditions. The experiment took place over 43 days from June 7 to July 19, 2012, with 14 days for vegetation sampling, and 17 days for soil moisture sampling. The soil moisture sampling days used a dozen field teams measuring moisture with handheld probes, concurrent to two aircraft flown with passive and active L-band microwave sensors, similar to those to be used on the SMAP satellite.

The study area for the SMAPVEX12 was an approximately 70 x 12 km area in southern Manitoba, Canada. Within the region, 55 agricultural fields of ~800x800m size were chosen for ground collection of surface soil moisture and vegetation water content. The agricultural fields consisted of the major crop types in the area, and included bean/soybean, corn, wheat/winter wheat, canola, pasture and forage. The study area straddled a sharp transition of surface soil texture with the eastern portion dominated by heavy clay soils and the west composed of much coarser sandy textured soil. The line of transition between these two surface texture classes occurs over only tens of meters in parts of the region.

Project Overview

The intensive ground sampling produced daily soil moisture values on each of the 55 fields in the area from 48 hand-held readings at 16 locations on each field, as well as daily vegetation parameters including water content, leaf area index, and canopy height for days that remotely sensed data were collected. Passive microwave data were gathered at 1.4 Ghz with a passive/active L-band sensor (PALS) at altitudes of 1 and 3 km corresponding to footprints of approximately 600 and 1500 meters. The higher resolution 600m passive data were gridded to the study fields by averaging the footprints that had a majority of their area within the field boundary. This created a field averaged brightness temperature with as little influence from surrounding terrain as possible. The ground-based soil moisture and vegetation water content measurements can be used to validate the high-resolution passive microwave soil moisture estimates, which can then be used to validate the lower resolution passive microwave data to examine the effect of scaling on moisture estimates.

9239-3, Session 1

Rainfall estimation with a commercial tool for satellite Internet in Ka band: concept and preliminary data analysis

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The problem of rainfall monitoring is a topic task in areas where precipitations are characterized by high intensity and very fast development. In fact, within these regions, the limits of the actual rainfall estimation approaches (i.e. rain-gauges, weather radars, satellite sensing, etc.) are represented either by the low rate of data acquisition or by the narrow area interested by the sensors. The employment of terrestrial and satellite microwave links to estimate the attenuation due to the rain event, are more suitable when real-time data over large areas are required, especially whenever multiple links that cover the same region are available. Actually, if multiple links forming a dense network are simultaneously available (generally this is true in urban areas), then it is possible to apply tomographic inversion algorithms to obtain a real time estimation of rainfall rate fields over a large area.

In this paper we discuss a real time method for rainfall estimation based on data acquired via Ka band satellite link and we present the preliminary results of its application. The data to be processed are recorded with a commercial kit for satellite web supplied by a European provider. The employed satellite link operates over the urban area of Florence (Tuscany): the receiver is located at the Department of Information Engineering of Florence University (43.7982 N, 11.2525 E) and the parabola has elevation and azimuth of respectively 39.45 and 183.25 degrees. The kit, namely Tooway2 system by EutelSat, operates in Ka band (29.5 – 30 GHz in uplink and 19.7 – 20.2 GHz in downlink) and it automatically performs an attenuation estimation of the signal received by the satellite, in order to adjust the power of the transmitted signal. The adopted model for the attenuation of a link due to hydrometeors is the suggested by Olsen and Hodge and recommended by the ITU.

The attenuation data (or better, the adjusted transmitted power) are directly available via the Tooway2 web interface. This information is processed in time domain and the results are interpreted together with registered rain-rate measurements provided by three rain-gauges from the Regional Monitoring Service dislocated within the area of Florence.

From this preliminary study it clearly appears that, accounting for a few inaccuracies (probably due to the position of the rain sensors and/or to the distributed nature of the weather events), the analyzed data are consistent with that collected by the considered rain-gauges. The proposed study represents indeed a first step in the development of a real time technique for rainfall estimation over large areas trough signal attenuation.

9239-4, Session 1

The effect of land cover type on radar altimeter response and its influence on retracker algorithms

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Satellite altimeters onboard Envisat and SARAL (Altika) are routinely used to measure water level in water bodies. Although the primary function of these altimeters is to monitor ocean levels they are increasingly used for monitoring large rivers and lakes. Based on radar technology in K- and C-band, satellite altimeters record point-impulse returns from nadir within a rather large footprint (approximately 8 km for Envisat and 4 km for Altika). Virtual monitoring stations can be created from the crossing of the satellite path (or track) with any river of significant width. These virtual station have the advantage of having a very low cost of operation (compared with manually operated stations) and providing near real-time absolute measurements of water level. However, many shortcomings still remain open questions and the precision of measurements can vary widely depending on a number of factors such as the river width but also environmental conditions surrounding the water course. In this article we have concentrated our efforts on the relation between land cover classes, the shape of waveforms produced by the backscatter response and the separability among different land cover classes and water. Land cover classes were determined by visual analysis of RapidEye images, and GoogleEarth. Of all the original classes of land cover in our classification, we only retained the eight classes with the largest areas within our study: agriculture, native forest, planted forest (eucalyptus), savanna, pasture, urban, wetland and open water. We first analyzed the waveforms recorded by the satellite in the six different land cover classes to build a database of typical response for each one. Hypothesis testing was used to determine the separability between the land cover classes and a simplified version with only four classes: water, non-water highly reflective, non-water medium reflective and non-water poorly reflective. We then analyzed the combined effect of the three non-water classes with water within the same footprint at a river crossing. Our results show that it can be difficult to separate all land cover classes solely based on the backscattering coefficients and that a classification in high- mid- and low-reflection was more efficient. This is partly due to the fact that we did not have access to precise elevation data that also influences the response. We concluded that the strongest the contrast between water and the surrounding land cover, the better the altimetry precision attainable. Although SARAL has a smaller footprint and a higher recording frequency than its predecessor (Envisat), its tracker tended to fail more often in region of steep slope. These points are currently under investigation. We expect that a better understanding of the influence of land cover and topography will increase accuracy of water level measurements.

9239-5, Session 1

A study on the use of passive microwave radiometry for the detection of buried objects and their associated hydrological changes

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The detection of buried objects with remote sensing techniques mainly relies on thermal infrared, ground penetrating radar, and metal detectors. However, nowadays people also start to use low frequency passive microwave radiometry for the same purpose. The main benefit of passive microwave radiometry towards the other techniques is the fact that it will give you information about the dielectric and thermal properties of the subsurface of approximately the first meter without being in contact with that surface. Recent advances in this technology created the opportunity to do this with a spatial resolution of just one meter.

The detection performance itself is influenced by the depth and size of the object, environmental factors, and soil properties. Soil moisture is a key variable here, due to its strong influence on the observed dielectric constant. Recent research in buried object detection mainly focussed on the improvement of algorithms and sensors or understanding soil properties (1), but less on the direct effects to the ground when placing an object in the soil. When a soil is disturbed, the hydrological conditions will change significantly which can as well be detected by remotely sensing systems.

A study was designed to examine the influence of the hydrological changes caused by the placement of an object in the ground. The soil moisture distribution around an object in a sandy soil and its influence on measured brightness temperature by passive microwave radiometry was analysed by simulations. A soil moisture model (2) was used to determine

the hydrological effects, when an empty 40x29x25cm object was buried under 20cm sand soil. The initial hydrological conditions above the container were assumed to have average temperature and soil moisture values. The model simulated different weather scenarios for which the varying hydrological conditions were analysed. The simulated observations were converted to brightness temperatures with a coherent model (3) in combination with a dielectric mixing model (4).

Simulations revealed that the soil moisture distribution above the object, differed significantly from a situation without an object. A wetter region above the object was developed during infiltration and a drier area underneath the object. Measured brightness temperatures decreased as a result of the wetter region above the object in respect to the surrounding soil moisture content. The caused hydrological disturbance, by placing the object in the soil, has a significant influence on the brightness temperature. In case of dry weather conditions, is the hydrological disturbance still visible after a few days of burying the object. These results illustrate that knowledge of past weather conditions could improve buried object detection by passive microwave sensors.

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9239-6, Session 2

Combining land surface models and remote sensing data to estimate evapotranspiration for drought monitoring in Europe *(Invited Paper)*

Carmelo Cammalleri, European Commission Joint Research Ctr. (Italy); Guadalupe Sepulcre-Cantó, Univ. Catholique de Louvain (Belgium); Juergen Vogt, European Commission Joint Research Ctr. (Italy)

The main hydrologic feedback from the land-surface to the atmosphere is the evapotranspiration, ET, which embraces the response of both shallow soil and vegetated surface to the atmospheric forcing (e.g., precipitation and temperature), as well as determines atmospheric humidity, cloud formation and precipitation, the main driver for drought. Actual ET is regulated by several factors, including biological quantities (e.g., rooting depth, leaf area, fraction of absorbed photosynthetically active radiation) and soil water status. The ET temporal dynamic is strongly affected by rainfall deficits, and in turn it represents a robust proxy of the effects of water shortage on plants. These characteristics make ET a promising quantity for monitoring agricultural drought, defined as a shortage of water availability that reduces the ecosystem productivity.

In the last few decades, the capability to accurately model ET over large areas in a spatial-distributed fashion has increased notably. Most of the improvements in this field are related to the increasing availability of remote sensing data, and the achievements in modeling of ET-related quantities.

Here, the potentiality of ET maps obtained by combining land-surface models and remote sensing data is explored, with a special focus on the reliability of ET (and derived standardized variables) as drought indicator. Tests were performed over Europe at moderate spatial resolution (1-5 km2), with the final goal to improve the estimation of soil water status as a contribution to the European Drought Observatory (EDO, http://edo.jrc.ec.europa.eu).

9239-8, Session 2

Surface soil water content estimation based on thermal inertia and bayesian smoothing

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Soil water content plays a key role in hydrology and agricultural sciences. In hydrology, it is critical for the partition between surface runoff and infiltration. In agricultural sciences the knowledge of its spatial distribution may be used to assess the presence of crop water stress in support to irrigation advisory services such as IRRISAT in the Campania Region (www.irrisat.it). This study aims to complement the procedures adopted in IRRISAT to monitor agro-hydrological variables with the estimation of the water content in the upper layer of the soil by coupling optical and thermal images in the thermal inertia approach. The proposed approach leads to accurate results in bare soil or sparse vegetation conditions. In this scenario, MODIS data have been proven to be useful to produce soil water content maps on large areas with a spatial resolution of about 1 km.

More in detail, the evaluation of the thermal inertia relies on the availability of the shortwave albedo and of, at least, two daily thermographs preferable acquired in specific epochs of the day (e.g., those characterized by the minimum and maximum surface soil temperature). Unfortunately, available thermal images are often acquired in less suitable hours, depending on satellite passes, thus leading to a less accurate estimation of the thermal inertia and hence of the surface soil water content. Moreover, the thermal inertia theory is developed under a "clear sky during the whole daytime" assumption, so its correct application requires knowledge of the cloud coverage, which unfortunately is hardly appreciated from MODIS images alone.

In this perspective the present paper, following previous contributions by the same authors [1 - 3], proposes that SEVIRI data, characterized by a lower spatial resolution but higher acquisition rate, be exploited to supplement MODIS data in a twofold way: i) allowing to verify, by means of suitable cloud detection algorithms, the hypothesis of clear sky throughout the daytime; 2) synthesizing a high spatial/high temporal resolution sequence of images, by fusing MODIS and SEVIRI data via Bayesian smoothing, which leads to improved soil moisture estimation.

The accuracy of the proposed estimation method is demonstrated through both a point assessment, namely by comparing the results with in situ soil water content measured by meteorological stations; and a wide area assessment, namely by comparison with soil water content maps at lower spatial resolution derived from radar data.

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9239-9, Session 2

Temperature monitoring along the Rhine River based on airborne thermal infrared remote sensing: qualitative results compared to satellite data and validation with in situ measurements

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Water temperature is an important parameter of water quality and influences other physical and chemical parameters. It also directly influences the survival and growth of animal and plant species in river ecosystems. In situ measurements do not allow for a total spatial coverage of water bodies and rivers that is necessary for monitoring and research at the Federal Institute of Hydrology (BfG), Germany. Hence, the ability of different remote sensing products to identify and investigate water inflows and water temperatures in Federal waterways is evaluated within the research project “Remote sensing of water surface temperature”. The research area for a case study is the Upper and Middle Rhine River from the barrage in Iffezheim to Koblenz.

Satellite products (e.g. Landsat and ASTER imagery) can only be used for rivers at least twice as wide as the spatial resolution of the satellite images. They can help to identify different water bodies only at tributaries with larger inflow volume (Main and Mosel) or larger temperature differences between the inflowing and the river water (power plants working with high capacity). To identify and investigate also smaller water inflows and temperature differences, thermal data with higher ground resolution and better thermal resolution is required.

An aerial survey of the research area was conducted in late October 2013. Data of the surface was acquired with two camera systems, a digital camera with R, G, B, and Near-IR channels, and a thermal imaging camera measuring the radiance temperature in the 8-12mum wavelength region. The resolution of the TIR camera allowed for a ground resolution of 4m, covering the whole width of the main stream and larger branches. The RGB and NIR data allowed to eliminate land surface temperatures from the analysis and to identify clouds and shadows present during the data acquisition. In situ measurements from water quality measurement stations and specifically deployed temperature loggers were used for the analysis and assessment of the remote sensing data.

The analysis of the data showed that low sun angles and hard shadows on the water surface in the Middle Rhine valley did not affect the thermal measurements of the water surface temperature. Due to mixing no differences were visible at the shadow border. However, influences on the net radiation in these areas were not investigated. Inflows with differing water temperatures could be identified successfully even for smaller dischargers and the mixing processes of water bodies with different temperatures could be traced into great detail.

Two alternative methods to correct for atmospheric influences were evaluated: calibration based on in situ water temperature measurements and atmospheric correction based on atmospheric parameters modelled with MODTRAN5®. Both methods rely on input data, the former on in situ measurements of the water temperature, the latter on data from climate stations. The results are validated by a data set of independent in situ measurements. Depending on the chosen input parameters and model, the variance of the atmospheric correction proved to be larger than of the in situ calibration method.

9239-10, Session 2

Integration of the Standardized Precipitation Index (SPI) and remote sensing for drought monitoring in Sulaimaniya, the Kurdistan region of Iraq

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Drought has dramatically affected Kurdistan region and the other parts of Iraq throughout the last years which characterized by a large drop in the rainfall averages. Geoinformatics (Geographic Information System GIS , Remote Sensing RS , and Global Positioning System GPS) has played a key role in monitoring, mapping, and assesses different types of hazards either natural or man-made. Three Landsat images acquired in September of 1990, 2007, and 2008 which covered Sulaimaniya governorate were utilized for the purposes of this study. Six Landsat based indices; the Normalized Difference Vegetation Index NDVI, Transformed Soil Adjusted Vegetation Index TSAVI, Tassel Cap Greeness TCG, Tasseled Cap Wetness TCW, Land Surface Temperature LST, and Normalized Differential Water Index NDWI, as well as to the Standardized Precipitation Index SPI as a meteorological index have been used. The aim of this study was to investigate the role of an integration of remotely sensed based indices and the SPI index for drought monitoring in Sulaimaniya governorate, the Iraqi Kurdistan region during the years 1990, 2007, and 2008. The spectral and meteorological indices were employed to monitor the drought status and its impacts in the study area. Change detection was applied to the resultant thematic images to estimate the spatiotemporal changes that happened between the years 1990 and 2008, and for detection the drought severity as well. The study results revealed that a severe drought has occurred in Sulaimani governorate in 2008, whereas the lowest SPI value was -2.122 observed in Ahmad Awa site. Similarly, the drought of 2008 led to a significant decrease in the vegetative cover, water surface area, soil/vegetation moisture, and to an increase in the barren soil areas. The drought affected severely on the vegetation cover in the study area that was significantly declined by 28.4% in 2008 compared with 2007. Likewise there were significant shrinkage in the water surface bodies areas such as the lakes in the study area. A Lake Dukan surface area was significantly shrank by 16.5 and 32.5 % in 2007 and 2008, respectively compared with 1990. Moreover, Lake Darbandikhan was shrunk seriously to become a pond and a small stream in 2008. It is further confirmed that the NDVI was performing well for depicting the vegetation cover and was more realistic than the other vegetation indices that has been used in the study. Significant correlations were found between the SPI index and the total Calcium Carbonate and the Cation Exchange Capacity CEC in the soil samples of the study area. The combined NDVI-SPI indices maps were produced and revealed that a worst and a severe drought was taking place in the Sulaimaniya district in 2008. The integrated indices can be employed as an efficient tool for drought monitoring, and in regional water resources management. Since Iraq is characterized by arid and semi-arid climatic conditions, It can be concluded that the use of combined indices of NDVI-SPI provides more reliable results for drought monitoring in the study area than any single index.

9239-13, Session 3

Integrating remote sensing and conventional grazing/browsing models for modelling carrying capacity in Southern African rangelands

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Woody vegetation encroachment into grasslands or bush thickening is a global phenomenon transforming Southern African grassland systems into savanna-like landscapes. The estimation of woody vegetation is important to rangeland scientists and land managers, to assess its impact on grass production and to calculate grazing and browsing capacity. The assessment of grazing and browsing components is often challenging because agro-ecological landscapes of this region are largely characterized by small scale and heterogeneous land-cover or land-use patterns. We investigated the utility of high spatial resolution remote sensing data for modelling grazing and browsing capacity at the landscape level. Woody tree density or Tree Equivalents (TE) and Total Leaf Mass (LMAS) data were derived by using the Biomass Estimation for Canopy Volume (BECVOL) program. The Random Forest (RF) regression algorithm was assessed to establish relationships between these variables and vegetation indices (Simple Ratio and Normalized Difference Vegetation Index) calculated using the red and near infrared bands of SPOT5. The RF analysis predicted LMAS with R2 = 0.63 and a Root Mean Square Error (RMSE) of 1256 kg/ha compared to a mean of 2291kg/ha. TE was predicted with R2 = 0.55 and a RMSE = 1614 TE/ha compared to a mean of 3746 TE/ha. Next, spatial distribution maps of LMAS/ha and TE/ha were derived using separate RF regression models. The resultant maps were then used as input data into conventional grazing and browsing capacity models to calculate grazing and browse capacity maps for the study area. This study provides a sound platform for integrating currently available and future remote sensing satellite data into rangeland carrying capacity modelling and monitoring. Satellites with spectral characteristics such as the red-edge and yellow bands and high revisit times better than SPOT5 would fulfil the critical users need for a systematic, high resolution, synoptic measurements of the southern African rangelands.

9239-15, Session 3

A potential for the spectral configurations of Sentinel-2 to assess rangeland quality

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The European Space Agency (ESA) has embarked on the development of the Sentinel constellation. Sentinel-2 is intended to improve vegetation assessment at local to global scale. Rangeland quality assessment is crucial for planning and management of grazing areas. Well managed and improved grazing areas lead to high livestock production, which is a pillar of the rural economy and livelihoods. Leaf nitrogen (N) is an indicator of rangeland quality, and is crucial for understanding ecosystem function and services. Today, estimation of leaf N is possible using field and imaging spectroscopy. However, a few studies based on commercially available multispectral imageries such as WorldView-2 and RapidEye have shown the potential of the red-edge band for accurately predicting and mapping leaf N at the broad landscape. Sentinel-2 has two red edge bands. The objective of this study was to investigate the utility of the spectral configuration of Sentinel-2 for estimating leaf N concentration. Canopy reflectance was measured using the FieldSpec 3, Analytical Spectral Device (ASD) in concert with leaf sample collections for leaf N chemical analysis. Using the spectral response function of Sentinel 2, ASD reflectances were resampled to the spectral bands of Sentinel-2. Random Forest (RF) technique was used to predict leaf N using all 12 bands. Using leave-one-out cross validation, the RF model explained 90% of leaf N variation, with the root mean square error (RMSE) of 0.04 (6% of the mean). Interestingly, spectral bands centred at 705 nm (red edge) and two shortwave infrared centred at 2190 and 1610 nm were found to be important in predicting leaf N. These findings concur with previous studies based on spectroscopy or hyperspectral and RapidEye on the importance of shortwave infrared and red-edge reflectance in the estimation of leaf N. ESA's Sentinel 2 has a potential to estimate leaf N which is crucial for informing decision makers on rangeland condition monitoring.

9239-17, Session 3

Quantitative Assessment of Australian Plague Locust Habitats in the Inland of Eastern Australia using RS and GIS Technologies

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Australian Plague Locust, Chortoicetes terminifera (Walker), can rapidly increase in population size in the remote interior of eastern Australia under favourable habitat conditions and cause severe agricultural damage. To minimise losses, early-detection of locust outbreaks is essential to the implementation of preventive control. Quantitative measurement of locust habitat suitability is critical for improving the efficiency of ground and aerial surveys, and providing vital information for locust population forecasting. Here, routine locust survey by the Australian Plague Locust Commission (APLC) during 2003 and 2011 is investigated in relation to the habitat greenness derived from the fortnight composites of 250m MODIS NDVI images, and the significant rainfall events from the weekly 0.25°/25km grids of modelled rainfall observations, using the spatial analysis and statistics tools of ESRI ArcGIS. The sighting dates of locust band were assigned into 5 groups corresponding to the locust nymphal stages, and the fortnightly NDVI values and weekly rainfall totals for the locations of locust bands were extracted for the previous 26 weeks. The averaged NDVI values for locust habitats showed a slight (0.01 – 0.07) increase 5 – 7 weeks before 2nd – 5th instar locust bands were sighted, but the median NDVI values increased by 0.05-0.12 from the initial greenness value of 0.23 – 0.27 during this period. The mean of NDVI anomalies confirmed this increase trend. However, 5th-instar bands consistently occurred where the NDVI value was higher before hatching, while 1st-instar bands were generally seen within drier conditions but where there was a ~25% NDVI increase some 12 weeks prior. Significant single rainfall events (>20mm) were required to trigger the locust breeding sequence, and in excess of 80mm total rainfall was required for locust nymphs to survive the entire nymphal period. These findings will improve the understanding of the mechanisms of locust plague related to habitat condition as well as potentially providing a practical method to monitor locust habitat conditions remotely and improve the underlying basis for locust survey and population management in Australia.

9239-19, Session 3

A simplified approach for localization of acacia cyanophylla in Akrotiri Cyprus using NDVI enhanced Quickbird imagery for classification

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Plant invasions represent a threat not only for biodiversity and ecosystem functioning but also for the character of traditional landscapes. Despite the worldwide efforts to control and eradicate invasive species, their menace grows. In order to manage invasion spices effectively and tackle with the impacts caused by individual trees, it is imperative to detect their presence with accuracy. Remote sensing classification has been a consolidated useful tool to map these spices but its application meets some limits in natural areas with trees and plants with similar growth characteristics. This study was conducted to identify with accuracy the plant invader acacia cyanophylla in the Sovereign Base Areas of Akrotiri in Cyprus, where many different species with similar characteristics are

present. The objective is to apply the appropriate measures so as to limit their growth using multiple remote sensing techniques. Given that a Quickbird satellite image with 4 channels was the only input for the classification, a fifth one was added out of the computation of the NDVI over the satellite image. NDVI being a complex function adds more information than a simple addition or multiplication between existing channels. Standard supervised classification using remote sensing software is compared with a new approach using simple statistical analysis on pixel-to-pixel basis and on a 3x3 moving window neighborhood. The results are compared to original training sets and are validated on the field for random sample areas. The proposed technique can be applied with UAV equipped with NIF cameras with smaller ground pixel size for more accurancy.

9239-21, Session 3

Identification of long-term trends in vegetation dynamics in the Guinea savannah region of Nigeria

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The availability of newly generated data from Advanced Very High Resolution Radiometer (AVHRR) covering the last three decades has broaden our understanding of vegetation dynamics (greening) from global to regional scale through quantification of inter-annual trends in vegetation time series and climatic variability especially in the guinea savannah region of Nigeria where greening trends is inconsistent . Due to the impact of global changes and sustainability of human lifestyle, increasing interest on vegetation productivity has become important. The aim of this study is to examine association between NDVI and rainfall using remotely sensed data, since vegetation dynamics (greening) has a high degree of association with weather parameters. This study therefore analyze trends in regional vegetation dynamics in Kogi state, Nigeria using AVHRR GIMMS 3g bi-monthly (Global Inventory Modelling and Mapping Studies) data and TAMSAT (Tropical Applications of Meteorology Satellite) monthly data both from 1983 to 2011 to identify changes in vegetation greenness over time. Analysis of changes in the seasonal variation of vegetation greenness and climatic drivers was conducted for selected locations to further understand the causes of observed inter-annual changes in vegetation dynamics. For this study, we use Mann Kendall (MK) monotonic method to analyze long-term inter-annual trends of NDVI and climatic variable. The MK test was used to measure the degree to which a trend is consistently increasing or decreasing, in which a value of +1 indicates a continuous increasing trend and a value of -1 shows a decreasing trend. The Theil-Sen median slope was used to calculate the rate of change in slopes between all pair wise combination and then assessing the median over time. The breakdown bound for the median is approximately 29%, which means the trends expressed in the image must have persisted for more than 29% of the length of the series (in time steps). The significance of the time series trend was calculated using the non-parametric Mann Kendall (MKz) significance test. The MK significance test is commonly used as a trend test for the TS median slope which produces outputs of z-scores that allows for the assessment of both the significance and direction of the trend. In the analysis, a positive slope ($z \geq 1.96$) represents a significant increase in NDVI for the period 1983-2011 and a positive slope of $z \geq 1.96$ represents a significant increase in rainfall at ? = 0.05 over time. Result of the NDVI trend analysis (monotonic) shows an increasing trend in the time series (? = 0.05). The significance of the result was tested using Kendall's tau rank correlation coefficient and the results shows an increasing monotonic trend in NDVI (tau > 0) which is referred to as greening. After the periodicity had been removed, the finding shows an increasing trend in vegetation greenness for one of the selected location with coefficient of determination value (R2) of 0.53. Linear regression between the monthly NDVI and TAMSAT rainfall data were performed and the coefficient of determination were evaluated. Although, increase in rainfall over the last decades enhances vegetation greenness, other factors such as land use change and population density need to be investigated in order to better explain changing trends of vegetation greening for the study area in the future.

9239-23, Session 3

Object based technique for delineation and mapping 15 tree species using VHR WorldView-2 (WV-2) imagery

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Monitoring and analyzing forests and trees are required task to manage and establish a good plan for the forest sustainability. Such care is requested due to their advantages as cleaning the air and water, and slow down the speed of the climate change through the photosynthesis process by reducing the carbon dioxide from the atmosphere. Therefore, information and data collection of the trees help to achieve aforementioned task. Satellite remote sensing techniques provide information in a faster way and relatively low cost. Several researchers utilized remote sensing to analyze the number of forest variables as tree species, size and density, volume and height, growth, and etc.. The variable of interest in this study is the tree species. Researchers classified and mapped at most 7 tree species in an urban area or forested areas using VHR images. However, in this study, we proposed an approach to identify and map 15 tree species in the Mangish sub - district, Kurdistan region-Iraq is used 8-bands WorldView-2 (WV-2) imagery. The species are Azarole hawthorn (Crataegus azarolus), Tera binth (Pistacia), Almand (Prunus duclis), Calabrain pine (Pinus brutia), Canary Islands Junipirus (Junipirus oxycedrus), Common fig (ficus carica), Common walnut (Juglans Nigra), Gall Oak (Quercus Infectoria), Jerusalem thorn (Parkinsonia aculeata), Oriental plane (Platanus orientalis), silver (Populus alba), Valonia Oak (Quercus aegilops), White Mulberry (Morus), White willow (Salix alba), and Oleaster (Elaeagnus angustifolia).

Image-objects (IOs) were used as the tree species mapping unit. This is achieved using the shadow index, normalized difference vegetation index and texture measurements. Four classification methods (Maximum Likelihood, Mahalanobis Distance, Neural Network, and Spectral Angel Mapper) were used to classify IOs using selected IO features derived from WV-2 imagery. Results showed that overall accuracy was increased 5-8% using the Neural Network method compared with other methods with a Kappa coefficient of 69%. This technique gives reasonable results of various tree species classifications by means of applying the Neural Network method with IOs techniques on WV-2 imagery.

9239-11, Session 4

Hemispherical directional reflectance factor using UAV and hyperspectral camera, validation and crop field test

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Small unmanned aerial vehicles are currently being used extensively for acquiring close range aerial images with high overlap. In most cases the end product is an orthoimage or a 3D model of the area. A huge amount of data is lost during this process, since in most cases the algorithms only use one intensity value for each ground pixel, even though that pixel can be found in multiple images. By utilizing the intensity and direction data content of the discarded pixels more information can be extracted from the data for no extra cost. The intensity and direction data can be used to build a Hemispherical Directional Reflectance Factor dataset which can be used for more advanced orthoimage intensity correction, or for extracting more information of the target. With the advancements in spectral imaging technology, more spectral

information can also be obtained during one flight, compared to a traditional RGB camera. With multiple spectral bands for each ground pixel, the classification of the targets is much easier, and even parameters such as plant chlorophyll content, plant stress and algae blooms in water bodies can be detected.

Small unmanned aerial vehicle (UAV) and a novel hyperspectral imaging camera (HSI) was used to measure the hemispherical directional reflectance factor (HDRF) of a test field with known light scattering properties. The HSI is a prototype manufactured by VTT Technical Research Centre of Finland. The HSI acquires a burst of 24 images within two seconds and all of these images are acquired with different spectral content from 500 to 900 nm. It utilizes a Fabry-Perot interferometer to rapidly change the optical transmission between acquiring each image. By using the autopilot of the UAV, the flight can be preplanned so that the target area is optimally covered with overlapping oblique and vertical images from multiple view angles. Structure from motion (SFM) algorithm is used to accurately determine the view angles for each image and to construct the surface model of the area. The HDRF is calculated for each ground pixel by determining view directions from all of the images for that particular pixel. The pixel intensity values are then processed to reflectance by using a reference panel, which has been measured in laboratory with Finnish Geodetic Institute Field Goniospectrometer (FIGIFIGO). The UAV flight was performed over a test field with different color gravel targets. The targets have been also measured with the FIGIFIGO and this allows us to compare the UAV HDRF and the FIGIFIGO BRDF. A demonstration measurement was performed for a winter wheat field to display the potential of this method for crop monitoring. This measurement was performed early spring to assess the condition of the wheat after winter. This method for measuring the HDRF can be used for development of autonomous methods for reflectance characterization.

9239-12, Session 4

Suitability of DSM derived from remote sensing data for automatic drainage extraction

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Hydrological indexes calculation requires the existence of spatial data such as the drainage network, the hydrological basin and the contours. For the Greek territory this data can be extracted from the topographic maps of the Hellenic Military Geographical Service (HMGS) or from remote sensing data. In this study the suitability and the accuracy of spatial information derived from remote sensing data are controlled with reference to the respective information from the topographic maps of 1/50.000. DSM from ALOS, ASTER, SRTM and airphoto stereopairs has been used for the automatic extraction of the drainage network, the hydrological basin and the calculation of three hydrological indexes namely frequency, density and basin slope. The results are presented in this paper.

9239-14, Session 4

Multihazard risk analysis using the FP7 RASOR Platform

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RASOR (Rapid Analysis and Spatialisation and Of Risk) is a response to the Call for proposals FP7-SPACE-2013-1, addressing topic SPA.2013.1.1-06 “Stimulating development of downstream services and service evolution”. The main objective of RASOR is the development of a platform to perform multi-hazard risk analysis to support the full cycle of disaster management, including targeted support to critical infrastructure monitoring and climate change impact assessment. RASOR uses a scenario-driven query system to allow users to simulate future scenarios based on existing and assumed conditions, to compare with historical scenarios, and to model multi-hazard risk both before and during an event.

The RASOR approach is to develop a risk assessment methodology mainly focused on risk identification and analysis as a support for risk evaluation done by the End Users. Information on Hazard, Exposure and Vulnerability (risk equation) will be combined into a specifically designed platform that enables an easy way of building risk scenarios referring to multiple hazards (floods, earthquakes…), focusing on specific exposure characteristics (Population, Environment, Economy…) and on specific phases of Disaster Risk Reduction (Prevention, Recovery…). Considering the lack of a standard Digital Terrain Model (DTM) at a sufficient level of resolution, one of the main challenges in risk assessment is to apply currently available DTMs (like SRTM) to real scenarios (flooding, for ex). Within RASOR, the newly developed 12m resolution TanDEM-X Digital Elevation Model (DEM) will be adapted to risk management applications, using it as a base layer to interrogate data sets and develop specific disaster scenarios. Satellite data is also a critical component of the RASOR tool. Baseline optical and radar data will be ingested into the system in order to extract exposure information tied to built-up areas, critical infrastructure, roads and access and many other features. Continuous (time series) and discontinuous InSAR data will be acquired for the analysis of the geohazard components based on ground deformation monitoring. Near-real time data may also be necessary when the rapid risk assessment is based on a dynamic situation and used during the warning phase, or in support of urgent decisions during recovery. Acquisitions from the ESA future Sentinel mission will also be used for the platform development.

Five case study areas are considered within the project, located in Haiti, Indonesia, Netherlands, Italy and Greece. Once the feasibility of RASOR objectives is demonstrated in these areas, RASOR plans a second Phase to develop a global prototype available to support global applications.

9239-16, Session 4

Evapotranspiration and energy balance components spatial distribution in the north region of Minas Gerais, Brazil, using the SEBAL model and Landsat 5 TM images

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The determination of ET values is very useful information for planning irrigation, water supply estimation, regulation of water rights and river basins hydrologic studies. Values of ET in the North region of Minas Gerais state, Brazil, were estimated in this research from the multispectral images of the Landsat 5 TM by means of the model Surface Energy Balance Algorithm for Land- SEBAL, based on the simplified energy balance equation of a surface covered by vegetation, using a few daily surface climatological parameters (wind speed, rainfall, air temperature and relative humidity, solar radiation). The aim of this study was to estimate the regional spatial distribution of the energy balance components and evapotranspiration in the study area, covering the irrigated perimeter of Gorutuba, involving the cities of Nova Porteirinha, Janaúba, Porteirinha, Verdelândia and Pai Pedro. Thematic maps of regional evapotranspiration and energy balance components were generated from spectral analyzes of the images obtained, associated with the used weather data. The ability of SEBAL to provide the spatial variability of energy balance components, including evapotranspiration, demonstrated its sensitivity to different occupation of the soil surface vegetation, and to high data temporal and spatial resolutions data, indicating that the SEBAL model can be used in scales and operational routine for north region of Minas Gerais.

9239-18, Session 4

A sampling strategy based on CGM for LAI measurements over non-uniform surface

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Currently, the remotely sensed product compared by measurements of field reference targets is still the basic means for validation. Limited by the representativeness of point sampling, all of the field measurements covering the whole region should be collected, which is impossible. Taking the cost of field measurement into account, more representative points with minimum number should be selected during remotely sensed product validation. There are several sampling strategies are used for remotely sensed product validation, including simple random sampling strategy, spatial uniform sampling strategy, Prior knowledge-based sampling strategy and so on. However, without fully considering the influence of the surface spatial heterogeneity, those sampling strategies often reduce the reliability of products validation. In this paper, a new sampling strategy based on computational geometry model (CGM) is proposed for leaf area index (LAI) ground measurement over non-uniform surface, as shown in Figure 1. Firstly, a correlation index (CI) is calculated based on high-resolution LAI image to choose the points of field measurement. Secondly, based on the first selected field measurements, the CGM model is used for simulating low-resolution LAI. Thirdly, the points of field measurement are decided according to the gaps between the simulated LAI and the aggregated LAI from high resolution. If the gap is accepted, the sampling strategy is finally established for field measurement. Otherwise, the field measurements should be re-selected and analyzed until the gap is accepted.

In this paper, sampling strategy for LAI validation over non-uniform surface is analyzed and compared with traditional sampling strategies. The results (Figure 2) show that, the uncertainty of simple random and classification-based sampling strategies have greater volatility than that of spatial uniform and CGM-based sampling strategies. With the increase in sample number, the uncertainty of traditional sampling strategies becomes lower, however, is still not ideal. The CGM-based sampling strategy efficiently reduces the error caused by model non-linearity and spatial heterogeneity during LAI validation and the maximum uncertainty is only 3.7%. The optimal sample number can be determined considering the cost-effectiveness, in this study, the field measurement number of 140 is chosen as the optimal number with uncertainty of 3.3% for whole image with number of 2500.

In conclusions, the paper proposed a new sampling strategy based on CGM for LAI measurements over non-uniform surface. This method linked the field measurements and parameters retrieved from satellite data, solving the scale effect between field point data and satellite pixel data and can be finally applied for the determination of locations of field measurements. However, there are still some deficiencies of the CGM-based sampling strategy, for example, the calculation is often time-consuming and effected by the land surface object. The CGM-based sampling strategy should be applied on other parameters in different places for further evaluation and improvement.

9239-20, Session 4

Linking in situ LAI and fine resolution remote sensing data to estimate the reference LAI for the coarse resolution satellite LAI products validation based on the geostatistical regression

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Leaf Area Index (LAI) is an important parameter of vegetation structure and function, and has been used widely in climate model. A number of regional and global moderate resolution LAI products have been produced by needing of large scale vegetation monitoring. High resolution LAI reference map is necessary to validate these moderate resolution LAI products. This study uses Geostatistical Regression (GR) model to reconstruct the high resolution LAI reference map through fusing field LAI measurements and Landsat TM/ETM+ data. The two Bigfoot sites, ARGO and HARV, whose vegetation types are crop and forest respectively, and one site in Hulun Buir, China with vegetation type of grass, are selected for this study. To explore the difference of employing different Bands reflectance or vegetation indexes (VIs) on estimating LAI reference map, this study establish the GR model for band 4, EVI, NDVI and RVI, respectively. To further assess the performance of GR model, this study compares the results with that estimated by Reduced Major Axis (RMA) model, which is the 'standard' method of BigFoot project on LAI reference map estimation. The results show that the performances of GR and RMA model using different explanatory variables are different at the three sites. GR model based on EVI has the best estimation at AGRO site, and for HARV site, the best estimation for GR model is based on RVI. However, GR and RMA model have the consistent performance at the three study sites, respectively. For example, both GR and RMA model have the best estimating ability based on EVI at AGRO site. For all of the three sites, The results of GR model are superior to those of RMA in terms of RMSE. Although the Bias of RMA model at HARV site is slightly lower than that of GR model, the Bias of GR model at AGRO and Hulun Buir sites are lower than that of RMA model. In addition, the results estimated by RMA model have much more abnormal values, whereas, the high resolution LAI map estimated by GR model is smoother.

9239-24, Session 5

River basin scale water accounting for the planning of irrigated agriculture *(Invited Paper)*

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Irrigated agriculture is an essential component of the rural economy in many river basins. Long term investments in commercial farming and the local agribusiness, makes it difficult to put a halt on irrigation activities. Yet, water shortage is a common element of many irrigated river basins in semi-arid and arid climates. Surface water is becoming rapidly a constraint for keeping the agro-sector healthy. The short term solution of many irrigators is to switch to groundwater exploitation, but this is not a sustainable practice. Many irrigated river basins are in a situation where the total volume of evapotranspiration surpasses the total precipitation. The extra evapotranspiration can be ascribed to these groundwater irrigation practices, and this should discontinue. There is an urgent need to introduce standardized water accounting procedures that quantifies the watershed processes, assesses a safe level of exploitable water volumes and fixes the maximum amount of water that could be withdrawn and consumed by the irrigation sector. The total evapotranspiration of river basins must gradually reduce and become controlled and regulated, in particular by reducing future groundwater abstractions. Examples of a new water accounting system based on satellite data and outputs of global hydrological models that determines the water flows – including groundwater flows - in irrigated river basins will be demonstrated using standard water metrics. WA+ can be used within its intrinsic uncertainty bounds to assess management options to reverse the depletion of aquifers, provide a safe allocation to the irrigation sector and ensures water remains available for necessary ecosystem services. The presentation will focus on the essence of having open-access and reliable earth observation data that is available for all stakeholders in river basins with competing water resources and inconvenient data sharing practices.

9239-25, Session 5

Energy balance with Landsat images in irrigated central pivots with corn crop in the São Paulo State, Brazil

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One of the main Brazilian food crops is corn (Zea mays L.), which has been cultivated for human consumption or animal feed. For the rational irrigation management, applications of tools are important for understanding the energy and water exchange processes between this crop and the lower atmosphere. The energy balance (EB) components were quantified in a commercial farm with corn crop, irrigated by central pivots, in the northwestern side of São Paulo state. The SAFER (Simple Algorithm For Evapotranspiration Retrieving) was applied to retrieve the latent heat flux (?E) considering five pivots covering irrigated areas from 74 to 108 ha. The basic remote sensing parameters were surface albedo (?0) and the Normalized Difference Vegetation Index (NDVI), used together with air temperature (Ta), global solar radiation (RG) and reference evapotranspiration (ET0) from an agrometeorological station close to the farm. ?0 and NDVI were calculated with only the Landsat visible and near infra-red bands and after obtaining net radiation (Rn) through the Slob equation, T0 was estimated by the residual in the radiation balance. With ?E obtained from SAFER and G as a fraction of Rn, H was acquired as a residual in the energy balance equation. Eight satellite images, covering together all crop stages from 23 April 2010 to 29 August 2010, allowed relating the energy balance components according to the accumulated degree-days (DDac) from the planting to harvest dates, which was in average 2130 oC for the entire growing season (GS). ?0 ranged from 0.20 at the initial stage to 0.16 between the bloom and grain-filling stages, while T0 followed the RG curve, staying between 298 and 314 K. NDVI values, from 0.18 to 0.75 were strongly correlated with DDac by a second order polynomial equation (R2 = 0.85). Net radiation (Rn) values ranging from 5.2 to 7.2 MJ d-1, represented 31 to 45% of RG. Considering the variation of the energy balance components along the corn crop growing season, the ranges for ?E, H and G were respectively 0.03 to 6.43 MJ d-1, -1.44 to 6.69 MJ d-1 and 0.13 to 0.47 MJ d-1. The fractions of Rn used as G were small, around 0.04, and for water management purposes, could be neglected at daily time scale. The fraction of the available energy (Rn - G) used as ?E was from 0.00 to 1.29, while for H it was between -0.29 and 1.00. Much variation of ?E and H, detected by standard deviation (SD) of 1.52 MJ d-1 for both fluxes were during the vegetative growth stage. ?E higher than Rn and the negative H/Rn happening four times along the corn growing season occurred after the vegetative growth and before the harvest time, indicated heat advection from the surrounding areas to the irrigation pivots, which represents an additional energy source for the evaporative process. The models applied here with only the visible and infrared bands of the Landsat sensor are very useful for energy balance analyses considering the size of the irrigation central pivots of corn crop in Brazil.

9239-26, Session 5

Improvements in irrigation system modelling when using remotely-sensed ET for calibration

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Irrigation system modelling is often used to aid decision-makers in the agricultural sector. It gives insight on the consequences of potential farm management and infrastructure changes. However, running an irrigation system water distribution model requires a considerable amount of input data to properly represent the system, which is not easily acquired or available. During the simulation process, several assumptions have to be made and the calibration is usually performed only with flow measurements. The advancements of estimating ET using remote sensing is a welcome asset for irrigation system modelling. Remotely-sensed ET can be used as input to the model; consequently the water balance and the crop production can be estimated by the irrigation system model with a better accuracy.

This study makes use of the Ador-Simulation irrigation system model, which simulates water flows in irritation districts in both the canal infrastructure and on-field. ET is estimated using an energy balance model, namely the Two Source Model, which has been proven to function well for agricultural areas. The advantage of this model is the integration of both the soil and plant interactions with the atmosphere. Cloudless images are used from the Landsat TM sensor. The thermal bands are corrected to achieve at surface temperatures using Modtran. The Two Source Model is run using SETMI, which is an interface in the ArcGIS environment developed by the Utah State University Remote Sensing Lab. The output from the model provides instantaneous ET estimates, which is used as input/calibration of the Ador model. The chosen study area is an irrigation area in Northern Utah, the Bear River Canal Company. This irrigation area encompasses 26,800 ha and mainly practices surface irrigation. The main crops are alfalfa, maize and small grains.

This application of remote sensing as a tool for irrigation system modelling indicates its practical use and value for agricultural irrigation management. The study elaborates on using remote sensing as a technology for achieving ET estimations. Then the results are brought to a higher level by applying it for practical purposes in an irrigation system model, thereby aiding irrigation managers.

9239-27, Session 5

Estimation of land surface albedo time series and trends based on MODIS data

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The land surface albedo is among the most important parameters controlling the atmospheric radiation fluxes and the surface–atmosphere interactions. In the present study, land surface albedo parameters and atmospheric aerosol optical thickness (AOT) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, onboard NASA's Terra and Aqua satellites, were analyzed and processed for the estimation of the shortwave land surface albedo over Europe, Northern Africa and the Middle East, at 1 km ? 1 km spatial resolution and on an 8–day average basis, for the period 2001–2012. The land surface albedo was computed as a linear combination of black and white sky albedo, corresponding to the direct and diffuse downwelling radiation components at the surface, respectively (Schaepman–Strub et al., 2006). The methodology used here, described in Schaaf et al., 2002, is based on a look–up table approach, which allows the computation of land surface albedo for different values of AOT and solar zenith angle (SZA). Simultaneous (8–day average) MODIS Level 3 AOT data, acquired over the entire study area from both Terra and Aqua platforms, were used in the computations, while the surface albedo was calculated as an average of albedo values, estimated using different SZAs on a pixel basis. The product created using this methodology was analyzed in terms of spatial and seasonal characteristics, and inter–annual trends, during the 12–year period examined. A strong dependency of the land surface albedo on land cover type was found. The results also revealed substantial spatiotemporal variability of the surface albedo in the area examined, highlighting the great potential of satellite remote sensing in studies related to the surface albedo and its role on climate, at both local and regional scales.

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9239-28, Session 6

Spectral and lag-correlation analysis of turbulence over a vine canopy in central California *(Invited Paper)*

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The physical processes that influence turbulence transport over a vineyard surface are investigated using spectral and co-spectral analysis. Turbulent-flow dynamics over agricultural surfaces play an important role in the transport of scalar quantities between the surface and the over-lying surface boundary layer. For many "smooth" agricultural surfaces, row structure is generally not considered to significantly affect turbulence in the surface layer; however, vineyards present a unique case where row spacing and vertical roughness elements are considerably different than those found in typical agricultural crops (e.g. maize, wheat, pastures etc.). The geometry of a vineyard over the course of a growing season changes with increasing vegetation growth. Additionally the physical row spacing which is substantially greater than typical row crops presents a continuum of repeated bluff body obstacles that imparts unique turbulent characteristics in response to changing wind directions. Transcending from the surface boundary–layer through the surface roughness layer can impact the surface energy balance partitioning and thus affecting vine evaporation rates and amounts. In a mature vineyard located near Lodi, CA (U.S.A.) two 10 m towers were erected in vineyards approximately 0.5 km apart. One was an established mature vineyard and the second a newly planted vineyard. The towers were instrumented with a full surface energy balance system at a height of 5 m. Each tower was also instrumented with three additional sonic anemometers beginning at 2 m above the vines up to 9 m above the ground surface. In this study, high frequency (20 Hz) vertical profile turbulence measurements of wind components u, v, w and the virtual sonic temperature T using sonic anemometers at 2, 3.75 and 9 m over a mature/young vineyard surfaces were conducted. Spectral analysis were performed for various components of wind speed, momentum and sensible heat for various conditions of vegetative stage growth, surface layer stability and temporal periods representing spring, mid-summer and early fall conditions. Initial results reveal distinct differences evolve across the growing season and in direct response to changing wind directions and speed. Enhanced momentum and heat flux transport to and away from the vine surface suggest coherent turbulence structures significantly affect surface energy partitioning and in particular evapotranspiration.

9239-29, Session 6

Vineyard zonal management for grape quality assessment by combining airborne remote sensed imagery and soil sensors

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Vineyard variability within the fields is well known by grape growers, producing different plant responses and fruit characteristics. The main sources of this variation come from climate conditions, plant genetics and, mainly, from soil. Many technologies have been developed in last recent decades in order to assess vineyard spatial variability, including remote sensing and soil sensors. In this paper we study the possibility of creating a classification system that better provides useful information for the grower. That means a better arrangement of the different management zones, either for irrigation, pest spraying, grape quality batches sorting, etc. The work was carried out during 4 years in a rain-fed Tempranillo vineyard located in Rioja (Spain). Multispectral imagery was acquired at véraison (that is the start of the ripening period) in years 2010, 2011, 2012 and 2013. NDVI was calculated as in indicator of vine vigor. Soil conductivity (EC) data was acquired in 2011 by an EM38 sensor mounted on a quad. Forty-two vines were sampled and 12 more were added in 2012 and 2013. Vine sampling included vegetation measures at véraison and yield-grape measures immediately before harvest. At véraison, total shoot length and total leaf area per shoot were measured as an indicator of vine vigor and photosynthetical ability. Before harvest, yield per vine and bunch weight were measured in the field. Samples of berries were packed for subsequent laboratory analysis. Then, berry weight, sugars, pH, total acidity, anthocyanins and total phenolics were determined. An Isocluster unsupervised classification in two classes was performed in 5 different ways: taking into account (a) NDVI map of the year of study "NDVIi", (b) Soil EC map "EC", (c) NDVI of the year of study and soil EC maps "NDVIi&EC", (d) NDVI maps of the four years of study together "NDVIS" and (e) NDVI of all the years and soil EC maps "NDVIS&EC". The target vines were assigned in different zones depending on the clustering combination. Analysis of variance and LSD Fisher comparison was performed for all parameters in order to verify the ability of the combinations to provide the most accurate information. All combinations showed a similar behaviour concerning vegetative parameters, differencing the two zones. Yield parameters classify better by the EC-based clustering, whilst maturity grape parameters seemed to give more accuracy by the "NDVI all years & EC" combination. Quality grape parameters (anthocyanins and phenolics), presented similar results for all combinations except for NDVIi, where the results were poorer. This results reveal that stable parametres (EC or/and NDVI all-together) clustering outcomes in better information for a vineyard zonal management strategy.

9239-30, Session 6

E.O.-based estimation of evapotranspiration and crop water requirements for vineyards: a case study in Southern Italy

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No Abstract Available

9239-31, Session 6

Estimating evapotranspiration of vineyards using high-resolution airborne multispectral and thermal imagery

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No Abstract Available

9239-32, Session 7

Analyzing C-band SAR polarimetric information for crop yield estimations

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In this study Radarsat-2 data and crop specific information from the ESA-led AgriSAR 2009 campaign is used for analyzing correlations between radar backscatter parameters and crop yields. The crop types canola, peas and wheat were analyzed and since these crops differ considerably in terms of structure, phenological development and grain type, the results show indeed that each crop requires specific radar analysis and explanation. For example, the peak value of a fitted function through the HV backscatter for peas results in high correlation values while the peak value of the fitted function through the coherence values between HH and VV offer the best results for wheat.

The site of study is the agricultural site Indian Head in Canada, which holds a wide variety of crops including cereals, oilseed and pulse crops. Over 80% of the farmed land is zero-till with single pass seeding and fertilization. The measurements include optical and radar data from RapidEye and Radarsat-2 respectively. The main derived measurements from the optical sensor include Leaf Area Index (LAI), which is based on NDVI values. The radar information includes the quad-polarisation product, including the covariance matrix, which enables the generation of backscatter values (powers in HV, HH and VV), their corresponding coherences, and derived parameters including the Cloude-Pottier Decomposition parameters (entropy, anisotropy, alpha angle). The radar data was captured in Fine-Quad mode, resulting in a spatial resolution of 5.4x8m. For this study, though, the data on field-level were used, meaning that the radar and optical data were averaged per field segment. The optical data consist of seven images radar data was acquired over 57 instances with varying beam angles.

The LAI values from optical data in combination with ground-surveyed LAI and pictures taken at ground level of the crops allow for understanding of the crop physical status. Interestingly, the peak of LAI generally comes before the peak of cross polarization backscatter, which implies that the transmitted signal is depolarized by the multiple reflections likely indicating denser biomass. Also, since the fields are generally subjective to swathing of the crop before harvesting, these abrupt changes in vegetation matter result in changing radar indicator values. Finally, the varying beam angles over time allow for empirical analysis with respect to their behavior with growing crops.

9239-33, Session 7

Coupling MODIS images and agrometeorological data for agricultural water productivity analyses in the Mato Grosso State, Brazil

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Mato Grosso Brazilian State has been highlighted by the grain production, mainly soybean as first (November-March) and corn second harvest (April-August) crops, respectively. The other main vegetation types include pasture, “Cerrado” (Brazilian savannah) and remaining forests. For water productivity (WP) analyses, the MOD13Q1 product from MODIS sensor, together with 34 agrometeorological stations in the State were used. Evapotranspiration (ET) and biomass production (BIO) were calculated at 16 days interval, during the year of 2012, applying an agricultural mask to separate crops from the other surface types, being WP considered as the ratio of BIO to ET. Monteith’s radiation model was used for estimating the absorbed photosynthetically active radiation (APAR), while SAFER (Simple Algorithm For Evapotranspiration Retrieving) was applied to retrieve ET. The basic remote sensing parameters were surface albedo (?0), surface temperature (T0) and the Normalized Difference Vegetation Index (NDVI). ?0 and NDVI were calculated with the MODIS bands 1 and 2 and after obtaining net radiation (Rn) through the Slob equation, T0 was estimated by the residual in the radiation balance, assuring all WP parameters at a 250 m spatial resolution. Considering agricultural crops for the whole state, the mean ET pixel values were between 0.4 and 3.1 mm d-1, while for other surface types this range was from 1.2 to 2.0 mm d-1. For BIO, these ranges were from 5 to 154 and between 43 and 87 kg ha d-1, respectively. Taking into account WP values, the corresponding ones were from 1.3 to 4.7 and between 3.1 and 4.7, being two crop growing seasons clearly detected, associated to the first and second harvest crops. ET, BIO and WP from agricultural crops above of those from other vegetation types, happened only from November to January with incremental values reaching to 1.2 mm day-1; 67 kg ha day-1; and 0.7 kg m-3, respectively; and between March and May, attaining 0.5 mm day-1; 27 kg ha day-1; and 0.3 kg m-3, respectively. In both cases, the crop stages the highest WP parameters in agricultural areas corresponded to the blooming to grain filling transition, while for other vegetation types the WP parameters were more stable throughout the year. Highlighting the corn crop, which nowadays is increasing in terms of cultivated areas in the State, the growing regions North, Southeast and Northeast were extracted from the whole State and analyzed. Southeast region presented the highest pixel averages for ET, BIO and WP (1.7 mm day-1, 78 kg ha-1 day-1, e 3.9 kg m-3, respectively); while for Northeast they had the lowest ones (1.2 mm day-1, 52 kg ha-1 dia-1e 3.4 kg m-3). Throughout a soil moisture indicator, the ratio of precipitation (P) to ET, it was indeed noted that rainfall was enough for a good grain yield, with P/ET values lower than 1.00 only outside the crop growing seasons. The models applied with only the red and infrared bands of the MODIS sensor are considered very useful for water productivity analyses under land use change conditions at medium spatial resolution scale.

9239-34, Session 7

A Spectral-spatial-dynamic Hierarchical Bayesian (SSD-HB) Model for estimating soybean yield

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Soybean production volume in Brazil is the second largest in the world; therefore the soybean is an important agricultural product and the production volume is increasing every year in Brazil. There are several factors contributing to this, the biggest one is the development of acid soil called the Cerrad. About 200 million ha wasteland has been turned into farm fields. Because farm fields in Brazil are very large, it is difficult to grasp the situation of the entire fields by farmer’s field examination. Therefore satellite image which can obtain wide-range information is very useful for field monitoring and management. Satellite data is used in crop growth understanding, harvest order determination, yield estimation, and so on. Especially for yield estimation, regression methods such as LASSO and multiple regression method using indicators such as NDVI have been used commonly.

However adding farming information such as weather data and varieties of crops which greatly affects yield is difficult in these methods. Because the multicollinearity caused by using many high-correlation parameters result in the low accuracy estimation.

In this paper, we proposed a new method called Spectral Spatial Dynamic Bayesian Model (SSD-HB) based on Bayesian model which can deal with many parameters such as spectral and weather information all together by reducing the occurrence of multicollinearity. Experimental results conducted in Brazil fields with RapidEye image indicate that SSD-HB model can predict soybean yield with higher degree of accuracy than the estimation method commonly used in remote sensing applications. The mean absolute error between estimated yield of the target area and actual yield is 0.19 t/ha, and it shows the potential effectiveness of our proposed method.

9239-35, Session 7

Estimation of corn and soybeans yield using remote sensing and crop yield data in the United States

Nari Kim, Yang-won Lee, Pukyong National Univ. (Korea, Republic of)

The crop yield estimation is essential for the food security and the economic development of any nation. Particularly, the United States is the world largest grain exporter, and the total amount of corn exported from the U.S. accounted for 49.2% of the world corn trade in 2010 and 2011. Thus, accurate estimation of crop yield in U.S. is very significant for not only the U.S. crop producers but also decision makers of food importing countries. Estimating the crop yield using remote sensing data plays an important role in the Agricultural Sector, and it is actively discussed and studied in many countries. This is because remote sensing can observe the large areas repetitively. Consequently, the use of various techniques based on remote sensing data is steadily increasing to accurately estimate for crop yield. Therefore, the objective of this study is to forecast the accurate yield of corn and soybeans using remote sensing and crop yield data in the United States. The input parameters derived from remote sensing data such as the Moderate Resolution Imaging Spectroradiometer (MODIS) and crop yield data were obtained from the National Agricultural Statistical Service (NASS) of the U.S. Department of Agriculture (USDA). We construct the crop yield estimation model for the decade (2001-2010) and perform predictions and validation for 2011 and 2012.

9239-36, Session 7

Evaluation of winter wheat yield prediction by assimilation of three different leaf area index datasets into the WOFOST model

Jianxi Huang, Junming Liu, Wei Su, Xiaodong Zhang, Dehai Zhu, China Agricultural Univ. (China)

To predict regional-scale winter wheat yield, we developed a framework to assimilate leaf area index (LAI) values derived by remote sensing into the WOFOST crop growth model. We measured LAI during seven main phenological phases in 53 sample plots in two districts of China's Hebei Province. To eliminate cloud contamination, we applied a Savitzky-Golay (S-G) filtering algorithm to the MODIS LAI products to obtain filtered LAIs. We established regression models between field-measured LAI and Landsat TM vegetation indices and derived multi-temporal TM LAIs. We developed a nonlinear method to obtain an adjusted LAI that accounted for the scale mismatch between the observations and crop models. We assimilated these three LAI datasets into the WOFOST model to allow an evaluation of yield prediction accuracy. We constructed a cost function using four-dimensional variational data assimilation (4DVAR) to account for the observations and modeled errors during key phenological stages. We used the SCE-UA algorithm to minimize the cost function between the time series of remotely sensed LAI and the modeled LAI and to optimize two important WOFOST parameters. We also evaluated the importance of LAI in each phenological stage. Finally, we simulated winter wheat yield in a 1-km grid for cells with at least 50% of their area occupied by winter wheat using WOFOST with the two optimized parameters, and aggregated to the county-level results at the regional scale. Our results showed that the current MODIS LAI products are not suitable for assimilation into the WOFOST crop growth model, because they tend to force the WOFOST model to reach unrealistically low crop LAI and yield values. Assimilating TM LAI in three phenological stages played a limited role in improving the model's performance. Heading LAI played the dominant role in improving assimilation accuracy compared with LAI during other phenological stages. In addition, using pre-heading LAI was more effective for improving the model's performance than using post-heading LAI. The nonlinear adjustment method that we developed to account for the scale discrepancy between crop models and the MODIS LAI time series, combined with a pixel purity map, improved our ability to account for spatial heterogeneity in the 1-km wheat pixels. Validation showed that our scale adjustment approach generated an accurate LAI trajectory throughout the growing season and improved the agreement between the scale-adjusted LAI and the field-measured LAI. By assimilating the time series of scale-adjusted LAI values, we greatly improved the estimates of wheat yield at field and regional scales. These results indicate that the proposed wheat yield estimation method using the 4DVAR strategy is a promising approach to wheat yield estimation at a regional scale, and provides a basis and a method to improve yield forecasting in other agricultural regions of the world.

9239-37, Session 8

Vegetation index correction to reduce background effects in orchards with high spatial resolution imagery

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Remote sensing provides alternatives for time consuming and labor intensive in situ measurements of biophysical variables, such as chlorophyll content, water content and leaf area index. However, despite the relatively high spatial resolution of current multispectral satellite sensors, remote sensing imagery over orchards will contain mixtures of canopies and backgrounds (i.e. soil, grass and shadow), which hamper estimation of biophysical variables. Current correction methodologies, such as soil-adjusted vegetation indices and signal unmixing, use spectral differences between canopies and backgrounds, but struggle to differentiate between spectrally similar vegetated orchard floors and canopies. The lack of a generic solution to reduce background effects irrespective of background types requires further investigation.

In a first step, the problem was demonstrated through synthetic imagery from a ray tracing model. Through a virtual orchard, realistic variations for biophysical variables were produced, while exact cover fractions, spectral signatures and biophysical variables of the target were known (i.e. chlorophyll and water content). Afterwards, a simple vegetation index correction method was proposed based on the mixing degree of each pixel. The correction method assumed that the pure canopy pixels were representative for the true range of index values (or biophysical variables). As a result, the vegetation indices were rescaled according to the mixing degree of each pixel (i.e. tree cover fraction), to represent the true index value of the contained canopies. This proposed method was compared to existing background correction methodologies, namely soil-adjusted vegetation indices (i.e. ratio of Transformed

Chlorophyll Absorption in Reflectance Index and Optimization of Soil-Adjusted Vegetation Index) and signal unmixing (i.e. Alternating Least Squares), for different backgrounds scenarios (i.e. uniform soil background and uniform weed background). Lastly, the proposed correction method was applied to a variable weed background to further illustrate the necessity and functionality of the proposed vegetation index correction.

The results of the uniform soil background scenario showed the inability of soil-adjusted vegetation indices to remove the background admixture effects. The signal unmixing and proposed methods removed most of the background influence for vegetation indices sensitive to chlorophyll (ΔR? = ~0.3; ΔRMSE = ~1.6 μg/cm?) and water content (ΔR? = ~0.3; ΔRMSE = ~0.5 mg/cm?). For the uniform weed background scenario, signal unmixing was not able to remove the background influences for chlorophyll content (ΔR? = -0.1; ΔRMSE = -0.6 μg/cm?), while the proposed correction method reduced background effects (ΔR? = 0.1; ΔRMSE = 0.4 μg/cm?). Moreover, the proposed method also corrected the background admixture in the variable weed background scenario for both chlorophyll and water content (ΔR? = 0.2 and 0.1; ; ΔRMSE = 1.4 μg/cm? and 0.5 mg/cm?).

In conclusion, the soil-adjusted vegetation indices were shown ineffective to correct the background effects, while signal unmixing removed most of the soil background influences, but was severely hampered by the spectral similarity between canopies and weeds. Both methods failed to provide a generic solution to the mixture problem, while the proposed vegetation index correction was successful irrespective of background type and could circumvent faulty management decisions, lower management costs and avoid production losses.

9239-38, Session 8

Insights and recommendations of use of UAV platforms in precision agriculture in Brazil

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The Interest in Unmanned Aerial Vehicles (UAVs) has grown around the world and several efforts are underway to integrate UAV operations routinely and safely into remote sensing applications, specially applied in precision agriculture. Despite advances in the past century, the UAV are still considered by many as being in its embryonic stage. The technologies that are being employed in UAVs today are evolving very fast and present with great promise. Systems autonomous are becoming more sophisticated and reliable. UAVs, by their potential for operations at low cost compared to manned aircraft, has become an ideal proposal for precision agriculture. Here we are summarizing those advances and the applications on precision agriculture in Brazil and showing an application with wavelet-multifractal multiscale analysis of information in citrus areas to detect HLB (Huanglongbing) infestations. It was studied for one year one area with 10 thousand trees. It was used multispectral image analysis and compared with conventional visual HLB detection. The results showed that it was possible to detect the HLB infestation, before the visual symptoms, with more than 90% of precision.

9239-39, Session 8

UAV-based hyperspectral monitoring of small freshwater area

Ilkka Pölönen, Hannu-Heikki Puupponen, Univ. of Jyväskylä (Finland); Eija Honkavaara, Finnish Geodetic Institute (Finland); Antti Lindfors, Luode Consulting Ltd. (Finland); Heikki Saari, VTT Technical Research Ctr. of Finland (Finland); Lauri Markelin, Teemu Hakala, Kimmo Nurminen, Finnish Geodetic Institute (Finland)

We have been studying utilization of Fabry-Perot interferometer based hyperspectral imager (FPI-HSI) in various applications. Previously we have been introducing applications in precision agriculture at SPIE RS.

Now we have utilized FPI-HSI in water area monitoring. In summer 2012 we imaged small freswater area from lightweight UAV. Simultaneously test samples were collected from the lake with accurate GPS position. We have existing spectral library for multiple different samples. This library is utilized to detect measured substances from water.

We will show pipeline to process FPI-HSI images to one coherent mosaic. There is couple of challenges when we are working on open water area. Our imaging campaign was executed relatively low (only 150 m). This indicates that our spatial resolution is quite high approx. 9 cm.

In this presentation (and paper) we will mostly concentrate to compare signature based target detection systems results to measured test samples. We will utilize some well known algorithms like SAM and SID, but our main interest is to build sub-pixel based target detection system, which could give us more accurate results, when we are estimating concentration of targets in freshwater.

Our sub-pixel based detection system's outline is:

1. Estimating number of endmembers in the image

2. Unmix delineated water area to find endmembers

3. Use SAM to compare target with found endmembers, if angle is enough small with some endmember it will be replaced with target otherwise we will add target as one of the endmembers

4. We will calculate invesion with set endmembers

As a result we have abundance image for the target. Now abundances of these image can be compared to measured test sample values. We will study how different spatial resolution (this is done with averaging) will effect on results. We will discuss if there is any real use for high spatial resolution hyperspectral remote sensing on water area.

9239-40, Session 8

Hyperspectral remote sensing for estimating coastal water quality: case study on the coast of Black Sea, Romania

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The North-Western part of the Black Sea is highly effected by eutrophication due to nutrient and sediment load inflow from the Danube River, which is the second largest delta in Europe. To get a general spatial picture of the water quality of the Romanian coast, It is not only time consuming but also hard to measure with traditional in-situ sampling. To solve these issues methods have been developed to use close-range spectral measurements for accurate and cheap assessments in real time for the concentrations of Chlorophyll-a, Phycocyanin, Total Suspended Matter and Coloured Dissolved Organic Matter in addition to water transparency. This paper presents the applicability of a state-of-the-art hand-held hyper-spectral sensor and a simple water turbidity indicator for monitoring water quality. The field work was conducted during the summer of 2013 on the Romanian coast of the Black Sea. The same techniques are used to calculate these parameters from satellite images (MODIS). The validation results and potential applications of the instruments will be discussed.

9239-41, Session 8

Hyperspectral band selection and classification of Hyperion image of Bhitarkanika mangrove ecosystem, eastern India

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Tropical mangrove forests along the coast evolve dynamically due to constant changes in the natural ecosystem and ecological cycle. Remote sensing has paved the way for periodic monitoring and conservation of such floristic resources, compared to the labour intensive in-situ observations. With the laboratory quality image spectra obtained from hyperspectral image data, species level discrimination in habitats and ecosystems is attainable. One of the essential steps before classification of hyperspectral image data is band selection. It is important to eliminate the redundant bands to mitigate the problems of Hughes effect that are likely to affect further image analysis and classification accuracy. This paper presents a methodology for the selection of appropriate hyperspectral bands from the EO-1 Hyperion image for the identification and mapping of mangrove species and coastal landcover types in the Bhitarkanika coastal forest region, eastern India. Band selection procedure follows class based elimination procedure and the separability of the classes are tested in the band selection process. Individual bands are de-correlated and redundant bands are removed from the bandwise correlation matrix. The percent contribution of class variance in each band is analysed from the factors of PCA component ranking. Spectral bands are selected from the wavelength groups and statistically tested. Further, the band selection procedure is compared with similar techniques (Band Index and Mutual information) for validation. The number of bands in the Hyperion image was reduced from 196 to 88 by the Factor-based ranking approach. Classification was performed by Support Vector Machine approach. It is observed that the proposed Factor-based ranking approach performed well in discriminating the mangrove species and other landcover units compared to the other statistical approaches. The predominant mangrove species Heritiera fomes, Excoecaria agallocha and Cynometra ramiflora are spectral identified and the health status of these species are assessed by the selected band. Further, the performance of this band selection approaches are evaluated in multi-sensor image fusion for better mapping of mangrove ecosystems, wherein spatial resolution is enhanced while retaining the optimal number of hyperspectral bands.

9239-43, Session 8

Hyperspectral measurements for discriminating natural vegetation in Sinai Sahara of Egypt

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Monitoring natural vegetation through remote sensing data in Egypt is just beginning. Only few studies were carried out to monitor Mangrove communities along Red Sea coast. ASD field spectroradiometer was used to measure spectral reflectance in the wavelength ranged from 350 to 2500 nm for 20 species belonging to the following genera Achille (one species), Aerva (one species), Alkanna (one species), Asclepias (one species), Astrraglus (one species), Ballota (one species), Echinops (one species), Fagonia (one species), Hyoscyamus (one species), Matthiola (two species), Origanu (one species), Peganum (one species), Phlomis (one species), Pyrethrum (one species), Stachys (one species), Teucrium (one species), Verbascum (one species), Zilla (one species), Zygophllum (one species). Then, hyperspectral reflectance characteristics and Macro/micro-morphological features were investigated. One Way ANOVA (Tukey's HSD Post Hoc Analysis) and Linear Discriminate Analysis were carried out to identify the optimal wavebands and wavelengths to classify the different genera with high pharmaceutical values. Generally, the results showed high matching between spectral characteristics and macro/micro-morphological features. It was found that red (550 - 750 nm) and SWIR-2 (2055 - 2315 nm) spectral zones were the optimal to discriminate the different genera. The specific wavelengths that could be used to isolate each genera were identified. It was found that Asclepias sinaic, Stachys aegyptiac and Verbascum sinaiticum could be clearly isolated from the rest of the genera with unique spectral characteristics. At the same time, no specific wavelengths were investigated for Alkanna orientalis and Fagonia glutinosa.

Key words: Hyper spectral, Natural vegetation

9239-44, Session 8

Hyperspectral indices for assessing damage by the red palm weevil Rhynchophorus ferrugineus (Coleoptera: Curculionidae) in date palms.

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The red palm weevil (RPW), Rhynchophorus ferrugineus (Olivier) (Coleoptera: Curculionidae) is a highly destructive pest of date palms, Phoenix dactylifera in several countries. The RPW larvae bore deep into palm crowns, trunks and offshoots, concealed from visual inspection until the palms are nearly dead. Traded palm trees are intensively transported between and within countries, spreading the pest worldwide. Consequently, an urgent need exists to identify and monitor concealed RPW larvae. Monitoring of this pest is generally error prone. Alternately, radiometry is a reliable technique for rapid and non-destructive assessment of plant health. The purpose of this research was to develop a mathematical method to automatically detect infested palm plant with RPW. A study was conducted to characterize reflectance spectra of palm plants with known red palm weevil infestation levels (grade-0 is healthy and grade-2 is severe), and seek to identify specific narrow wavelengths sensitive to RPW damage. Reflectance measurements were made in the spectral range of 350–2500 nm using a hyperspectral radiometer. Reflectance sensitivity analysis of the hyperspectral data to RPW damage also determined. Results of this study could suggest potential usage of remote sensing in monitoring spatial distribution of the RPW, and thereby enable effective planning and implementation of site-specific pest management practices. The study shows that it is feasible to detect RPW infestation using the hyperspectral data and recognize its level, which could be utilized to monitor trade and predictions.

9239-77, Session 8

Independent Component Analysis (ICA) performance to bathymetric estimation using high resolution satellite data in an estuarine environment

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The use of satellite remote sensing data is a valid alternative to the classical survey bathymetric methods for bathymetric estimation in shallow waters. Multispectral satellite data has been used to produce bathymetric maps by considering the pixel reflectance as a depth indicator [1]. Several methods

were already developed in order to produce bathymetric maps [2], [3]. These methods consisted in measuring the water attenuation by estimating the deep-water reflectance and the water depth with the assumption that the bottom reflectance attenuation is only due to the water column and therefore to the depth. Teodoro el at., (2010) already propose a model for the estimation of depth based on Principal Component Analysis (PCA) of an IKONOS-2 image, for the Douro River estuary (Porto, Portugal) [4]. In this work, a model for estimate the bathymetric value is proposed in this work based on Independent Component Analysis (ICA) of an IKONOS-2 image, for the Douro River estuary (Porto, Portugal). The PCA is the standard method for separating mixed signals. Such analysis provides signals that are linearly uncorrelated. Although the separated signals are uncorrelated they could still be depended, i.e., nonlinear correlation remains [5]. The ICA was developed to investigate such data. Fast ICA algorithm was used in Matlab®. The results obtained were compared with the bathymetric estimation trough PCA already performed. Best univariate ICA based model allowed to estimate the logarithm of depth with a mean absolute error of 0.37 (0.50 standard deviation), with improves to 0.34(0.46) in with a bivariate model. This outperforms the best PCA based models results 0.39(0.52), even for bivariate models using components that explain 87% of data variance.

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9239-64, Session PS

Detection of calcium carbide on fruits using imaging type two-dimensional Fourier spectroscopy

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Two-dimensional imaging-type Fourier-spectroscopy is the spectroscopic tomography method that can limit the measuring depth into the focal plane and is a near common-path interferometer with high robustness for the mechanical vibration. Because the two-dimensional imaging-type Fourier-spectroscopy is a wavefront-division-type interferometer, it could be obtained the spectroscopic tomography by scanning the focal plane into the depth direction. Calcium Carbide is used in some countries as source of acetylene gas, which is an artificial ripening agent. However, acetylene is not nearly as effective for ripening as is ethylene, and acetylene is not a natural plant hormone like ethylene. Also, calcium carbide may contain traces of arsenic and phosphorus, both highly toxic to humans, and the use of this chemical for ripening is illegal in most countries.?Absorption of infrared of acetylene lies in the region of mid infrared wave. Therefore, in this paper, presence of acetylene in fruits will be checked using imaging type two-dimensional Fourier spectroscopy.

9239-65, Session PS

The difference of normal segmentation method for unorganized point-cloud data generated by laser scanning: description and case studies for vegetation and buildings

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Segmentation of unorganized point-cloud data is a key procedure in 3D model construction. This is important for terrestrial laser scanning, whose data has proven to be an excellent tool for mapping applications ranging from as-built documentation to three-dimensional reconstruction of architectural details and building facades. In this study, we applied a novel segmentation algorithm for unorganized point-cloud data: the difference of normals method. We tested the method using campus and maize scenes at the China Agricultural University, and found clear segmentation of points belonging to various objects of interest at different scales, such as leaves, stalks, cars, and persons.

9239-68, Session PS

Retrieval of LAI and leaf chlorophyll content from remote sensing data by agronomy mechanism knowledge to solve the ill-posed inverse problem

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Monitoring crop growth parameters are important for acquiring knowledge of crop production and quality beforehand, and then giving agriculture planning and policy making at regional and national scales. LAI and leaf chlorophyll content, as the two most important crop growth variables, are the major foundation in management decisions. The use of vegetation remote sensing to assess crop growth conditions has been explored in last five decades and become a useful tool. The PROSAIL model, combined by the PROSPECT leaf optical properties model and the SAIL canopy bidirectional reflectance model, has used for about two decades to retrieve the vegetation biophysical properties. However, the ill-posed problem is unavoidable for the unique solution of the inverse problem and the measurement and model uncertainties.

Thus, the main objective of this study was to use agronomy mechanism knowledge to reduce the uncertainties associated to estimation of canopy biophysical variables in the radiative transfer model inversion process. A multi-objective genetic algorithm was used for inversion, and the prior knowledge of agronomy mechanism based on the relationship between LAI and LCC in winter wheat was restricted to remove the ill-posed inversion results. In order to demonstrate the effect of prior knowledge, inversion results of linked prior knowledge were compared with those from inversion results of the PROSAIL model alone.

Field experiments were carried out in 2009/2010 and 2012/2013 at the National Precision Agriculture Experimental Base of Xiaotangshan town (40o10'31" ~ 40o11'18" N, 116o26'10" ~ 116o27'05" E), Changping district, Beijing, PR China. Data acquisition included the canopy hyperspectral reflectance with the ASD FieldSpec Pro FR spectroradiometer, LAI with the CI-203 Handheld Laser Leaf Area Meter, and leaf pigment content with a colorimetric spectrophotometer, which were measured at the following stages: jointing (23 April 2010), heading (6 May

2010, 9 May 2013), anthesis (19 May 2010, 22 May 2013), and filling (1 June 2010, 29 June 2013) for winter wheat.

For the prior knowledge of agronomy mechanism, the established model based on LAI and LCC was learned from the theory on crop nitrogen uptake and allocation, where chlorophyll was mainly composed of nitrogen. Thus, the regression model was created between LAI and LCC by a power function. The relationship between ln(LAI) and ln(LCC), and the 95% confidence band for the regression line were demonstrated. Almost all scatters were within the 95% confidence band, and this gave us an inspiration that was to determine whether the inversion results of LAI and LCC were realistic or not. If the inversion results of LAI and LCC were scattered within the 95% confidence band, they were retained. If not, the inversion results were removed.

The inversion results with PROSAIL model with not prior knowledge of agronomy mechanism (NPK) and with PROSAIL model and prior knowledge of agronomy mechanism (PK) were compared, and the results showed that prior knowledge did not significantly improve the accuracy of LAI inversion. The R2 and RMSE were 0.635 and 1.022 for NPK, and 0.637 and 0.999 for PK, respectively. However, the inversion accuracy of leaf chlorophyll content (LCC) was significantly improved through combing prior knowledge. The R2 and RMSE were 15.6%, 0.377, 14.495 for NPK, and 0.503, and 10.661 for PK, respectively. The comparison results demonstrated that the necessary of prior knowledge of agronomy mechanism in PROSAIL model inversion.

9239-69, Session PS

Mangrove forest extraction and change detection in Sri Lanka

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Mangrove forests are unique and important ecosystems existing only in the inter-tidal zones between the seawater and the coastal land, supporting a wide variety of coastal species. They also have a function of disaster prevention, protecting coastal areas from tsunami and high tides by absorbing in wave energy. They are, however, disappearing at a rapid rate due to human activities such as industrial, residential, agricultural and aqua cultural development. It is urgently needed to investigate their current status and distribution, and take effective measures for the preservation of mangroves.

This paper describes the methodological study that developed for mapping mangrove forests using Random Forest classification method. The data of Landsat TM/ETM+ images and a digital elevation model that based on Shuttle Radar Topography Mission (SRTM) were used to extract mangrove forests of two decade in Sri Lanka. The extracted results agreed well with ground truth data and gave high accuracy with aerial photographs.

9239-70, Session PS

Validation of smoke plume rise models using ground-based Lidar

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Biomass fires can significantly degrade regional air quality through the emission of primary aerosols and the photochemical production of ozone and secondary aerosols. The injection height of smoke from biomass burning into the atmosphere ('plume rise height') is one of the critical factors determining the impact of fire emissions on air quality. Plume rise models are used to prescribe the vertical distribution of fire emissions which are critical input for the smoke dispersion and air quality models. While many plume rise models exist; their uncertainties, biases, and application limits when applied to biomass fires are not well characterized. The poor state of model evaluation is due in large part to a lack of appropriate observational datasets. We have initiated a research project to address this critical observation gap. A ground-based, mobile elastic scanning lidar (light detection and ranging) instrument and data-processing methodology have been developed at the US Forest Service Missoula Fire Science Laboratory to study the plume dynamics and the optical properties of smoke particles over open biomass fires. The data-processing methodology is applied to lidar observations to determine the heights of smoke plume layers (plume rise heights) and their temporal changes.

In August of 2013, the US Environmental Protection Agency (EPA) Region 10 led a comprehensive experiment to study smoke from agricultural fires in the US Pacific Northwest. The research included participants from the EPA, two US Forest Service laboratories, two universities, and several partner smoke management agencies. Our research team from the US Forest Service Missoula Fire Sciences Laboratory deployed a ground-based mobile, lidar and airborne atmospheric chemistry instruments and obtained measurements of plume rise heights for nine agricultural fires. The lidar measurements are combined with the coincident airborne measurements to provide an observational dataset of plume rise height and vertical profile of smoke density. These observations are being used to validate several plume rise models, including the Briggs equations which are used in several smoke management tools. We will present the validation results and provide recommendations regarding the application of the models to agricultural burning.

9239-71, Session PS

Crop monitoring using X-band SAR interferometry in the Lombardy region, Italy

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Synthetic Aperture Radar (SAR) interferometry is a useful technique for crop monitoring, especially when height and density are considered. In this study, COSMO-SkyMed X-band multi-temporal data acquired under three look-angles over a large area covering Pavia and Lodi provinces in the Lombardy region (northern Italy), were used for crop assessment through inteferometric coherence analysis. The availability of the data over the growing season in year 2013 (from February to November) made it possible to monitor the growth of two intensive agricultural crops (rice and maize), due to the correlation between X-band interferometric coherence and the crop height. The multi-temporal data were used to monitor the cultivation through repeat-pass interferometry. The capability of the discrimination between rice and maize cultivated parcels was also measured along with evaluating the coherence focusing on the seasonal peak and the cultivation density. The results of this study are intended to be included in a crop monitoring framework which integrates SAR and optical remote sensing techniques. In this framework optical data concentrates on monitoring the growth and discrimination of crops throughout the growing season while SAR data are a complementary source in order for overcoming some weaknesses and acquisition gaps of optical data.

9239-72, Session PS

Runoff estimation using satellite-derived rainfall data on Gapcheon watershed, South Korea

Kyung-Tak Kim, Joo-Hun Kim, Yun-Seok Choi, Korea Institute of Construction Technology (Korea, Republic of)

The objective of this study is to suggest a method for estimating rainfall-runoff relationship using runoff analysis with satellite rainfall and global geographic data for the region with lack of observed data.

In this study, the satellite rainfall data is achieved using CMORPH developed by NOAA CPC and GSMaP_NRT developed by the Japan Science and Technology Agency while the global geographic data is produced using GTOPO30 that has been developed based on data from 8 different institutions inlcuding NASA.

Also, the landuse/Landcover Map is acquired using GLCC developed with AVHRR data by USGS, University of Nebraska-Lincoln and European Commission's Joint Resesarch Centre. The spatial resolution of GLCC is 1km.

IFAS(Integrated Flood Analysis System) developed at ICHARM is used in this study.

The satellite-derived rainfall data of CMORPH and GSMap_NRT collected from June 1st to July 31st of 2012 is used. In the evaluation of the rainfall data, the correlation coefficients of CMORPH and GSMaP_NRT with observed data are 0.37 and 0.30 respectively.

The rainfall-runoff analysis was performed for Event #2 and Event #4 which are considered to be the two relatively large amount rainfall event. The correlation coefficients for Event #2 were 0.53 for CMORPH and 0.68 for GSMaP_NRT. The total rainfall were 119.5mm for ground gauges, 173.5mm for CMORPH and 71.1mm for GSMap_NRT. For Event #4, the correlation coefficients with respective to ground gauges were 0.56 for CMORPH and 0.37 for GSMaP_NRT. The total rainfall are 73.0mm, 61.1mm and 30.4mm for ground gauges, CMORPH and GSMaP_NRT, respectively.

For peak runoffs, the relative error of the observed data was 2.9% in Event #2 without the intermediate parameter adjusted. Event #4 showed a relative error of 63.3% before adjusting the parameter but a large decrease in the error after adjusting it.

Without correcting the parameter, the runoff analysis using IFAS also showed the error with peak runoffs resulting relatively small. Therefore, the methods suggested in this study could be applied to ungauged watershed. In the future, this study will analyze runoff for North Korea representing one of the most inaccessible regions by using satellite rainfall and global geographic data.

9239-74, Session PS

Remote sensing of climate changes effects on forest biophysical variables

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Management of forest ecosystems at landscape scales means projecting and evaluating interactions and cumulative impacts on many resources at a time. It requires an integration of observational data, science, practice, management experience. Understanding how land surfaces respond to climate change requires knowledge of land-surface processes, which control the degree to which interannual variability and mean trends in climatic variables affect the surface energy budget and by this forest vegetation. Use of remote sensing to monitor the forest changes due to climatic or anthropogenic stressors is an excellent example of the value of multispectral and multitemporal observations. Climate variability represents the ensemble of net radiation, precipitation, wind and temperature characteristic for a region in a certain time scale (e.g.monthly, seasonal annual). The temporal and/or spatial sensitivity of forest vegetation dynamics to climate variability is used to characterize the quantitative relationship between these two quantities in temporal and/or spatial scales. So, climate variability has a great impact on the forest vegetation dynamics. Forest vegetation phenology constitutes an efficient bio-indicator of climate and anthropogenic changes impacts and a key parameter for understanding and modeling vegetation-climate interactions. Satellite remote sensing is a very useful tool to assess the main phenological events based on tracking significant changes on temporal trajectories of forest biophysical parameters like as Normalized Difference Vegetation Index (NDVIs) and Leaf Aria Index (LAI), which requires time-series data with good time resolution, over homogeneous area, cloud-free and not affected by atmospheric and geometric effects and variations in sensor characteristics (calibration, spectral responses).A climate indicator (CI) was created from meteorological data (precipitation over net radiation). The relationships between the vegetation dynamics and the CI have been determined spatially and temporally. The driest test regions prove to be the most sensitive to climate impact. The spatial and temporal patterns of the mean NDVI are the same, while they are partially different for the seasonal difference. This paper will quantify this impact over a forest ecosystem placed in the North-Eastern part of Bucharest town, Romania, with Normalized Difference Vegetation Index (NDVI) parameter extracted from MODIS Terra/Aqua satellite data in synergy with meteorological data over 2000-2013 periods. For investigated test area, considerable NDVI decline was observed between 2003 and 2008 due to the drought events during 2003 and 2007 years. Under water stress conditions, environmental factors such as soil type, parent material, and topography are not correlated with NDVI dynamics. Specific aim of this paper was to assess, forecast, and mitigate the risks of climatic changes on forest ecosystem and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the basis of spectral information derived from satellite data regarding atmospheric effects of forest biome degradation. Specific aim of this paper was to assess, forecast, and mitigate the risks of climatic changes on forest ecosystem and its biodiversity as well as on adjacent environment areas and to provide early warning strategies on the basis of spectral information derived from satellite data regarding atmospheric effects of forest biome degradation .

9239-75, Session PS

Fitness evaluation of CMORPH satellite-derived precipitation data in the Korean Peninsula

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In this study, the level of accuracy of the induced rainfall data is evaluated by comparing observed ground-based data and CMORPH data for global rainfall estimated using the satellite provided by NOAA CPC. Based on this, the application possibility of this satellite-derived rainfall data to water resources field is analyzed.

Three regions - the whole area of South Korea(99,720?), Nakdong-river basin(23,384 ?) and Kumho-river basion(2,110?) - are targeted as regions of application of this study. The application of this study to the whole area of South Korea includes measurement of total annual precipitation and spatial distribution of the precipitation. For Nakdong-river basin and Kumho-river basin, analysis based on temporal resolution and spatial scale is performed.

As a result of analyzing the data of total 10 years collected from 2002 to 2011, the correlation coefficient of 1-day cumulative rainfall is averaged as 0.87 while that of total annual precipitation is calculated to be approximately 4 to 5 times different. The spatial distribution of the precipitation data from 69 meteorological stations and that of CMORPH appear to be similar.

For the analysis of temporal resolution, 3 hour, 1 hour, and 30 minute rainfall data are analyzed. The result shows that there is no trend in the correlation coefficient but the fluctuation of RMSE decreases as the temporal resolution becomes larger.

From the analysis of basin scale, it is shown that the analysis of accuracy of rainfall data improves as the basin scale increases. Moreover, the analysis result of RMSE shows that the fluctuation of the data decreases as the basin scale increases.

9239-76, Session PS

Land drainage system detection using IR and visual imaginary taken from autonomous mapping airship and evaluation of physical and spatial parameters of suggested method

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An experimental approach to the land drainage system detection and its spatial and physical parameters evaluation by the form of pilot project is presented in this paper. The novelty of the approach is partly based on using of unique unmanned aerial vehicle - airship with some specific properties. The most important parameters are carrying capacity (15 kg), long flight time (3 hours), high operating safety and special flight characteristics such as stability of flight, in terms of vibrations, and possibility to flight at a low speed. The high carrying capacity enables using of high quality sensors like professional IR camera FLIR SC645, high-end digital camera and optics in the visible spectrum and navigational grade INSGPS sensor iMAR iTracerRT-F200 in the case of this project.

A special instrumentation was installed for physical characteristic testing in the locality. The most important is 30 meter high tower with 3 meter length bracket at the top with sensors recording absolute and comparative temperature, humidity and wind speed and direction in several heights of the tower. There were also installed several measuring units recording local condition in 10 minutes interval (air temperature, humidity, wind speed, rainfall, incident and reflected radiating flow in IR and visual spectrum) in the locality. Recorded data were compared with IR images taken from airship platform. There were also measured tens of control points for testing of spatial characteristics (position and orientation of images) in the locality. These points were used for evaluation of cameras direct georeferencing.

The locality is situated around village Domanín in the Czech Republic and has size about 1.8 x 1.5 km. The most of locality area is non built-up except the village Domanín. There was build a land drainage system during the 70-ties of the last century which is made from burnt ceramic blocks placed about 70 cm below surface. The project documentation of the land drainage system exists but real state surveying haven´t been never realized.

The aim of the project was land surveying of land drainage system based on IR, visual and its combination high of resolution orthophoto (10 cm for VIS and 30 cm for IR) and spatial and physical parameters evaluation of the presented method. The results of the both objectives are presented in this paper.

9239-78, Session PS

Grassland ecosystem monitoring with remote sensing data

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The quality of grassland is directly related to the ecosystem of Qinghai Lake basin. Crude protein, crude fiber, crude fat are the main nutrition factors of the pasture quality. The reflected spectra of twelve types of grasslands were measured with ASD Field spec ground spectrometer from June to September in 2013, and samples of pastures were tested in laboratory to obtain the nutrient contents of crude protein, crude fiber, crude fat. Firstly, the reflectance spectra characteristics were preprocessed and analyzed. In order to reduce the interference of soil reflectance and the spectra measurement error, all the reflectance spectra were normalized, then the normalized difference vegetation index, ratio vegetation index, enhanced vegetation index, and the soil vegetation index, the wavelength position of red edge were also calculated, based on these reflectance spectra characteristics, the separability of different types of grasslands were analyzed. Secondly, the nutrient contents and their change features were studied with different types pasture and different seasons. Blysmus sinocompressus is the higher nutrition pasture with the crude protein content 16.55, and the Stipa purpurea has the higher crude fiber content of 38.21 for it does not turn green in June. Finally, the relationships between the grasslands vegetation index and the nutrition contents of pastures were analyzed, the results showed that it is more easier to recognize the poisonous weeds and the pastures when they are bloom in June for they bloom earlier than other pastures. There were similar reflectance spectra characteristics of deteriorated grasslands and the Dasiphora fruticosa which is a kind of scrub. The nutrition contents changed with seasons, and different types of grass have different growth period and that could be used to suggest the grazing routes based on the pasture nutrition changed with the seasons. The derivative spectrum and ratio spectrum were more obviously correlated with the nutrition contents than other vegetation index, the sensitive wavelengths of crude protein were at the near infrared and short wave infrared bands. The sensitive wavelengths of crude fiber and crude fat were at the short wave infrared bands, and the derivative spectrum models were the most suitable to estimate the crude fiber and the crude fat content with about 70% accuracy. This study indicated the nutrition contents of different types of pastures could be estimated with the hyper-spectral remote sensing data, and it is possible to monitor the quality of pasture with remote sensing technique. The reflectance spectra measurements were carried out in field, there were many disturbed factors effected the accuracy of the grass nutrition contents monitoring models with the reflectance spectra, and more experiments would be carry out in the field and in the laboratory to improve the precision of the pasture quality monitoring models with the spectral data.

9239-79, Session PS

Evapotranspiration in pastures with different indicators of degradation in the watershed of Alto Tocantins in Brazilian savanna

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The Watershed of Alto Tocantins, located in Brazilian Savanna (Cerrado biome), is in a rapid land use change process, causing large pressure on natural resources. Thus, the areas with pasture have high relevance for the rational use of natural resources allying economic and environmental sustainability. In this context, remote sensing techniques are important, for example, for obtaining relevant information to assess the vegetation degradation conditions on a large scale. This study aimed to use data from the MODIS sensor to obtain classes indicative of degraded pastures in the Watershed of Alto Tocantins as well as to apply Surface Algorithm For Retrieving Evapotranspiration (SAFER) together with field measurements in order to analyze the evapotranspiration (ET) in each class with indicatives of degradation of the potential production of pasture. In obtaining the classes indicative of degraded pastures used the NDVI product (synthesis of 16 days) for the period from January 2002 to December 2012. Then, SAFER

was applied and it was estimated ET in each class. In this case, we used a series of MODIS images of the year 2012 together with data from weather stations provided by the National Institute of Meteorology (INMET). The strongest degradation had higher concentration in pastures located in the top center and bottom of the Watershed of Alto Tocantins. It is worth noting that approximately 24 % of the areas planted pastures had some indication of degradation, and these areas are shown spatially distributed along the pastures. For the year 2012 it was observed that ET in the low degradation class was very close to the values found for the pasture areas of non-degraded class, and in some periods the class of low degradation had ET values equal or greater than found for the non-degraded class. In this case, in the driest period of the year there was no ET differences between classes with low degradation and non-degraded. Thus, the average ET of these two classes was around 1.50 ± 0.67 mm d-1. Factors related to pasture management and spatio-temporal heterogeneity of rainfall throughout the year, may have influenced these results. For the classes of moderate and strong degradation, were found ET average the order of 1.36 ± 0.66 mm d-1 and 1.05 ± 0.61 mm d-1, respectively. The average ET from all areas of pastures in the Watershed of Alto Tocantins was 1.35 mm d-1. Significant differences in ET were observed in areas of pasture according to the degree of degradation. These differences were more pronounced during the water stress in the ET values when were lower by up to 14.8 % and 59.2 % in pastures with moderate or strong indication of degradation, respectively. These results indicate changes in the partition of the energy balance in accordance with the loss of potential production of pasture areas.

9239-80, Session PS

Spectral reflectance of satellite images using geostatistics methods to estimate growth and cotton yield

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Many studies have focused on evaluating spectral indices in terms of their sensitivity to external factors affecting canopy reflectance and crop yield. Attempting to correlate the information of satellite images with the in-field spatial yield distribution, the objective of this study was the spatial identification of the NDVI (Normalized Difference Vegetation Index) and cotton yield distributions through different crop phenological dates using geostatistical methods in Goiás state, Brazil.. For this, multitemporal images were acquired using AWIFs imaging system from a typical cotton field. Yield data were also collected from this field using a cotton yield monitor.The experiment was carried out in a commercial field with 48.1 ha, in a 80m by 80m georreferenced grid with 74 plots. Yield monitor data and multispectral satellite images at 56m spatial resolution were collected in a rainfed cotton field in two dates to monitoring the plant vigor. The AWiFS (Advanced Wide Field Sensor) satellite images were acquired at 02/08/2011, during the first flowering stage of cotton (70 days after emergence (DAE)), and at 01/04/2011 on the fruiting stage at 110 DAE. Measures of canopy reflectance, plant height and leaf nitrogen content were determined and seed cotton yield was obtained by mechanical harvest in August. Data were analyzed using descriptive statistics, correlation analysis and geostatistical analysis by building and setting semivariograms and kriging interpolation. Correlation analysis between the cotton yield and NDVI in two evaluation dates, showed the best correlation with NDVI and cotton yield at 110 DAE. The NDVI at 70 DAE and cotton yield showed strong spatial dependence, while for 110 DAE it was not dependence, probably due the vegetated coverage enlarged. There were similarities in the bottom left of the area with high values of NDVI 70DAE, as well as the highest values of cotton yield due to excellent plant vigor in the cotton flowering stage. By using geostatistics methods with remote sensing data retrieving by satellite images of medium resolution it was possible an spatially identification of differences in plant development and predict with a good correlation the cotton yield.

9239-81, Session PS

A new algorithm for evapotranspiration estimation based on landscape metrics and geostatistics

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Evapotranspiration (ET) plays an important role in energy exchange and hydrological cycle between the land surface and atmosphere. Remote sensing (RS) has long been recognized as the most feasible means to provide spatially distributed regional ET since conventional methods(micrometeorological, climatological, or hydrological methods) are limited to point measurements, and meet great challenges when extended to large areas because high surface heterogeneity influences the driving force of ET process. Classical RS flux algorithms (SEBS, S-SEBI, SEBAL, etc.) may be suitable for assessing the surface fluxes with high resolution RS data, but will cause much larger bias when used with much coarser resolution data from sensors like MODIS (Moderate Resolution Imaging Spectroradiometer) or AVHRR (Advanced Very High Resolution Radiometer) in order to broaden the scope of their application since such algorithms can hardly discriminate the influence of surface heterogeneity in mixed pixels.

A new algorithm is developed in this study for improved ET estimation in coarse resolution RS data with landscape metrics and geostatistics parameters to take surface heterogeneity into consideration. First of all, one of the landscape metrics named Shannon's evenness index (SHEI) is selected and calculated at landscape level in coarse RS pixels since it can indicate the diversity and dominance in a certain area. Meanwhile, semi-variance parameters (such as nugget, sill and range) will also be calculated within the same pixels to evaluate the surface heterogeneity since they are extensively used in geostatistics to evaluate spatial variation and correlation. Then the force data which drives ET process such as albedo, emissivity, leaf area index (LAI), normalized difference vegetation index (NDVI) and land surface temperature (LST) will be retrieved from fine resolution RS data and aggregated to the coarser resolution pixel with a certain scaling-up technique as the " true" value without heterogeneity error. The true value will be compared to corresponding coarse resolution product from standard dataset to get a ratio which evaluates the error caused by surface heterogeneity. The ratio will be represented with the landscape metric and semi-variance parameters mentioned above to obtain more accurate flux gradients including net radiance, soil heat flux and sensible heat flux, leading to a more accurate ET estimates as a residual in energy balance equation. The algorithm will be applied to other regions for improved ET estimation when fine resolution RS data is out of hand.

The study is carried out in the core agricultural land of Zhangye, the middle reaches of Heihe river based on HJ-1B as the fine resolution RS data and MODIS as the coarse one. The algorithm will be used for an improved ET estimation in this area compared with MOD16.

9239-83, Session PS

Estimation of atmospheric downward longwave and shortwave radiation from MODIS data in polar regions

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The atmospheric downward longwave radiation (DLR) and shortwave radiation (DSR) are key components in polar land surface radiation budget and many land surface models that characterize hydrological, ecological and biogeochemical process. Compared with in-suit measurement limited to a small number of coastal stations, remote sensing (RS) is more suitable for global and long term evaluating of DSR and DLR. Many algorithms have been developed to estimate global downward radiation from remote sensing data for all sky

condition; however, they can hardly apply to the high-latitude regions since they seldom consider the extreme atmosphere conditions unique to polar regions, leading to huge bias of the estimation of polar downward radiation for all sky condition with remote sensing data.

In this paper we present an improved parametric model to estimate atmospheric clear sky DSR which contains direct radiation and diffuse radiation based on REST2 (2008) model and Stephens (1984) algorithm for improving a shortwave parameterization revised to improve cloud absorption in cloudy sky. The influence of highly reflective snow ice surface which enhances the multiple scattering radiation of DSR as well as the influence of high zenith angle, ozone hole and months-absence of solar radiation in polar regions are highly underlined and considered in this study. Meanwhile, DLR is also estimated with Yu model (2013) which takes the effect of low integrated water vapor into consideration in polar regions using MODIS data. Compared to empirical and conventional methods, the polar atmospheric conditions will be considered in this parametric model for an improved estimation of DSR and DLR in polar regions.

In this study, the MODIS products including MOD05_L2 (total precipitation water vapor), MOD06_L2 (cloud optical thickness), MOD07_L2 (atmosphere profile) and MOD021 (infrared TOA radiation), and MCD43B3 (white sky albedo and black sky albedo) are used as inputs to estimate DSR and DLR at 1 km resolution under all-sky conditions over polar regions. Then the reliability of the estimates and the associated errors are validated by in-suit measurements and compared with estimates of other models which give no thought of polar conditions. Based on this algorithm, an improved estimation of DSR and DLR in the high-latitude region are retrieved in 1-km resolution and improved the resolution of DSR and DLR compared to existing products.

9239-84, Session PS

Remote sensing of water level and ice cover of large and middle-sized lakes of Russia

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Studying of water level and ice cover of large and medium sized lakes are of interest because they represent natural reservoirs of fresh water and are associated with human economic activity. Moreover, the water level variations and ice cover duration are important indicators of climate changes. In addition to in situ observations satellite methods of monitoring have certain advantages connected with the global coverage, instantaneous observations of large water areas and relatively low cost. However, the use of satellite methods for inland waters is often difficult because of their spatial resolution comparable to or greater than the size of water reservoirs. Remote sensing with high spatial resolution is often associated with a large repeat period of data (ICESat), or with a significant dependence of the quality of data on weather conditions (Landsat). In this regard, the use of Jason -2 satellite equipped with dual-frequency (13.6 GHz and 5 GHz) radar altimeters and passive three-frequency (18, 21 and 37 GHz) microwave radiometers is of interest, because the footprint diameter of their altimeters in Ku-band is about 10 km and the repeat period of observations is ten days, that make it suitable for observations of large and medium-sized inland waters.

In this work we use the data of three mentioned above satellites to determine the water level variations and ice-cover régime of 8 lakes in Russia, water areas of which are intersected by the tracks of these satellites. Variations in water level is calculated on the base of retracking method [1] taking into account the fact that the waveforms of altimetry pulses of satellites Jason-2 and ICESat are distorted due to the influence of land. Satellite data are compared with available in situ observations and the correlation coefficient with in situ observations is calculated. The ice regime of lakes is determined using a new method [2] based on the analysis of the difference between the brightness temperatures of land and water in summer and winter periods. For validation of this method visual images of the lakes from Landsat satellites and in situ data are used.

[1] Yu.Troitskaya et al., “Adaptive retracking of Jason-1 altimetry data for inland waters: the example of the Gorky Reservoir”, Int. J. Rem. Sens., vol. 33, pp. 7559-7578, 2012.

[2] Rybushkina G.,Troitskaya Yu., Soustova I., “Ice and snow regimes of the Volga River reservoirs on the base of Jason-1,2 satellite observations”, Living Planet 2014 Symposium, Edinburg (UK), 9-13 Sept., 2013.

9239-85, Session PS

Simulating the spatial representativeness of the meteorological observed data on rugged terrain

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The accurate estimation of surface solar radiation (SSR) is affected by many factors in rugged terrain. As an input data of topographic correction model, DEM affects the spatial redistribution of SSR. As usual, the retrieved data will be validated by ground observations which can only provide point measurements on flat surface and can hardly represent conditions in complex terrain.

Empirical models are established in traditional meteorology to estimates SSR with large amount of ground observed data, which is impossible to obtain synchronously on large area in most countries. In addition, topographic correction methods of meteorology usually introduce into the empirical coefficients which were various by the different regions. The regional limitations and the great interpolation error in the spatial extension process are the disadvantages. Although remote sensing data is employed to retrieve SSR to make up for inadequacies of meteorology methods, it still remains inconclusive whether the DEM of high resolution or local scale can correct topographic influences properly since there are two problems remained to be solved: 1) the scale effect is existed in topographic correction for different radiation products with DEM of different resolutions, 2) whether the ground observations can represent the retrieved value from remote sensing data from the extension of “point” to “pixel”.

A series of different resolution DEM data will be generated by resampling the 30m resolution ASTER GDEM and will be employed in the topographic correction model for the horizontal SSR products. The radiation after correction will be linear fitted with the resolution (R) of DEM to establish a function SSR=f(R), in this function, SSR will increase in line with R and stabilize when R reaches a certain value, which will be regarded as the best scale of DEM in the topographic correction model.

In order to analysis the spatial representativeness, the test points will be fetched in different slope and different aspect at both pixel scale and sub-pixel scale (resampling the SSR products into smaller scale pixel) in the variogram model of geostatistics. The range (h) in variogram model represents the spatial extent of the ground observed data and indicates the ground observed data can represent the retrieved value in the local pixel if the h value is less than pixel resolution.

On the basic of a previous project which had provided the 1km horizontal SSR in China, this study will divide SSR into three components of energy, namely, direct radiation ( ), sky diffuse radiation ( ) and terrain reflected radiation ( ). Topographic correction of the three components will be performed to restore the real distribution with Mountain Radiometric Calibration Model which is based on radiative transfer theory.

Four different types of climate conditions and topography conditions study areas (Heihe, Lhasa, Beijing, Erjinaqi) will be selected to simulate the whole experiment process. Finally, the results that after spatial representativeness analysis will be used to verify with the ground observed data in the four areas.

9239-86, Session PS

Water productivity of different land uses in watersheds assessed from satellite imagery Landsat 5 Thematic Mapper

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Northeastern of São Paulo State is a agriculture region, where irrigation agriculture is the main water consume in this region. However, policy directives are calling for tools to aid operational monitoring in planning of use irrigation water. Water productivity (WP) of various land use class in the watersheds was estimated using of the SAFER - Simple Algorithm For Evapotranspiration Retrieving, and using with Monteith the model to estimate the parameters of biomass production (BIO). Monteith's equation was used to quantify the absorbed photosynthetically active radiation (APAR) and Actual Evapotranspiration (ET) was estimated by the algorithm SAFER. The objective of the study is to analysis in the spatial-temporal water productivity in watersheds with land cover types differents and driest conditions, during the period 1996-2010, using with Monteith the model to estimate the parameters of BIO and SAFER for determination of ET. Results indicated that the incremente rate ET value of 153.2% during the period 1997-2010, with the irrigated areas this increase in ET values. In September 2000, for image of day of year (DOY) 210 high values of BIO, with means of 80.67 kg ha-1d-1. In the year 2010 (DOY:177), the mean value of BIO was 62.90 kg ha-1d-1, with an irrigated area with a maximum value of 227.5 kg ha-1d-1. The highest incremental values of BIO is verified from the start of irrigated areas equal to the value of ET, because there is a relationship between BIO and ET. The maximum WP value occurred in June/2001, with 3,08 kg m-3, the second highest value was in 2010 (June/DOY:177), with a value of 2,97 kg m-3. Irrigated agriculture show the highest WP value, with maximum value of 6.7 kg m-3. The lowest WP was obtained for DOY 267 (September, 2008), because of the dry season with condition of low soil moisture.

9239-87, Session PS

biophysical parameters in wheat producer region in southern Brazil

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The Wheat (Triticum aestivum) is the second most-produced cereal in the world, with major importance in the global agricultural economy. Brazil is a great producer of wheat, with emphasis on Rio Grande do Sul state, located in the south of the country. The winter gramineous is highly susceptible to weather and climate conditions, characterized by intercropping system with soybean and maize, cultivated in summer, causing variations in amounts produced yearly. Faced with the variability in crop yield and economic importance of cereal, the purpose of this study is to analyze estimates of biophysical parameters of wheat crops for conditions monitoring of development and productivity, from satellite images and meteorological data. For this study, have been used daily data from 31 weather stations provided by National Institute of Meteorology (INMET), and performed the processing of MODIS (Moderate Resolution Imaging Spectroradiometer), product MOD13Q1, concerning the reflectance of bands 1 (?1) and 2 (?1), with spatial resolution of 250 m and temporal resolution of 16 days. The satellite images selected correspond to wheat agricultural calendar in the region, between June (planting) and November (harvest) year 2012, totaling 11 images. The SAFER (Simple Algorithm For Retrieving Evapotranspiration) model was applied to obtain evapotranspiration (ET) and biomass production (BIO). To obtain water productivity (WP) was applied the Monteith Model, obtained by the ratio of BIO and ET?. The results have been extracted for land use mask for Rio Grande do Sul state, available by Brazilian Institute of Geography and Statistics (IBGE). Based on the agricultural areas of southern Brazil occupied by wheat fields at the beginning of the cycle, the average ET values ??obtained were 1.17 ± 0.46 mm d-1, BIO presented average values ??of 34.28 ± 21.03 kg ha -1 and WP average values of 2.64 ± 0.77 WP kg m-3. To development of crops of wheat, can be observed variability of the parameters throughout the cycle. The biophysical parameters were higher at mid-cycle, related to period of maturation culture, therefore occurring a higher water loss to the atmosphere as evapotranspiration, higher biomass production and higher water productivity, as can be seen in the values ??of ET , BIO and PA, corresponding to 2.59 ± 0.68 mm.d-1, 100.46 ± 39.05 kg ha-1 and 3.72 ± 0.63 kg m -3, respectively. At the end of the crop cycle and harvest time, a reduction of biophysical parameters with ET average around 1.27 ± 0.89 mm.d-1, BIO average around 33.04 ± 32.03 kg ha -1 and WP 2.07 ± 0.81 kg m -3, respectively. The SAFER model proved effective on estimates of biophysical parameters evapotranspiration, biomass production and water productivity in areas planted with wheat in Rio Grande do Sul from the validation of the results with field data, the methodology can be used for monitoring of water conditions and biomass crop using satellite images, assisting in estimates of productivity and crop yield

9239-88, Session PS

Analysis of fraction of absorbed photosynthetically active radiation direct and diffuse characteristics based on long-term field automatic observation data

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Fraction of Absorbed Photosynthetically Active Radiation (FPAR) is the fraction of the incoming solar radiation in the Photosynthetically Active Radiation spectral region that is absorbed by a photosynthetic organism. This biophysical variable is directly related to the primary productivity of photosynthesis and some models use it to estimate the assimilation of carbon dioxide in vegetation.

Remote Sensing Inversion is an important method to get the vegetation canopy FPAR. The photosynthetically Active Radiation reached to plant canopy could be divided into two parts that are direct radiation and diffuse radiation. The paths into the vegetation canopy are different of these two kinds of radiation. We used SAIL model to simulate direct FPAR and diffuse FPAR in different condition. The result show that when the visibility is set as 5km, 15km and 30km, the contribution of scattering of FPAR on the total FPAR is 52.6%, 29.3% and 21.7%. The error between total FPAR and direct FPAR is reduced with the increasing of visibility and increased with the reducing of LAI. The maximum relative error is 13.2%. From the simulation analyses, we could see that direct and diffuse FPAR are different with the changes of environment variables. It is necessary to build a FPAR model which can divide these two parts.

In this paper, a photon flux sensor system was built and erected in the corn canopy to observe the FPAR change automatically. This system consists of 18 photon flux sensors. They were used to observe the received and reflection PAR on the top of canopy and on the bottom of the canopy. Since they are arranged in different orientations of corn plants, so

the observation data can reflect the impact of direct light and scattered light. This system will work during the whole growing season of the corn. So the change of weather and solar zenith angel can be recorded. These long-term observation can help us to explain the daily variation regularity of FPAR. Through the analysis of these observation data, a FPAR model was built to divide direct and diffuse radiation.

The validation of FPAR remote sensing data products is a problem because the observation data is difficult to obtain. Using this observation system, the long-term data can be obtained. At last, we used these observation data to validate the inversion FPAR.

9239-89, Session PS

Assessing Cd-induced stress from plant spectral response

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Remote sensing plays a significant role in local, regional and global monitoring of land covers. Ecological concerns worldwide determine the importance of remote sensing applications for the assessment of soil and vegetation health condition and identification of stress-induced changes. The expansion of industrial development and rapid urbanization pose serious ecological problems associated with the increasing anthropogenic pressure on the environment. Soil contamination is a reason for degradation processes and temporary or permanent decrease of the productive capacity of land. Heavy metals are among the most dangerous pollutants because of their high toxicity to organisms, persistent nature, easy up-take by plants and long biological half-life. This paper takes as its focus the study of crop species spectral response to Cd pollution. Ground-based experiments were performed, using alfalfa, spring barley and peas grown in Cd contaminated soils and in different hydroponic systems under varying concentrations of the heavy metal. Cd toxicity manifested itself by inhibition of plant growth and synthesis of photosynthetic pigments. Multispectral reflectance, absorbance and transmittance, as well as red and far red fluorescence were measured and examined for their suitability to detect differences in plant condition. Various spectral features proved to be indicators of plant performance and quantitative estimators of the degree of the Cd-induced stress.

9239-90, Session PS

The synergy of water quality and sea surface currents data in determining the spatio-temporal evolution of large-scale circulation features

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Chlorophyll-a (CHL-a) and Sea Surface Temperature (SST) are often considered indicators of water quality. Satellites easily provide synoptic view of these parameters almost in near-real time. However, physical forcing that drive their temporal and spatial variability, such as wind and currents, need to be determined and studied in detail, to assess their influence on circulation features and, consequently, in shaping the distribution of water quality parameters.

Satellite imagery (e.g., MODIS, VIIRS/NPP) provides a synoptic view of the spatial and temporal variability of SST and CHL-a; on the other hand, more conventional sampling of the ocean properties through in situ measurements, or the use of ocean circulation models, provide accurate site-specific data , and may offer inadequate representation of sub-grid physical processes. Additionally, satellite data and pointwise measurements lack either of the temporal or spatial resolution required to resolve the essential temporal variability, such as: tides, high-frequency wind-driven circulation, and sub-mesoscale flow features. Indeed, though providing regular time-series of ocean properties in the region, satellite data do not provide information on fine-scale features owing to their resolution of spatial structure and temporal variability at the coastal boundaries.

High-Frequency (HF) coastal radars provide useful information to support sea safety and sea monitoring, as they are capable of measuring sea-surface currents with high temporal (10 minutes – 3 hours) and spatial (500 m – 6 km) resolution. Designed originally for research purposes, their use spreads as well as for search-and-rescue activities and for water quality monitoring in coastal regions where, for instance, wastewater treatment and industrial plants could affect the water quality.

The use of HF radars is nowadays well established worldwide: sea surface currents of both east and west United States coasts are continuously monitored through HF radar networks. In Europe, the number of installations is increasing: several HF networks were already installed in Galicia (North-west Spain), Ría de Vigo (Galicia, Spain), Strait of Gibraltar (Iberian Peninsula, Irish Sea, Northern Scotland).

Recently, a network of HF radars was installed in the Sicily-Malta Channel, as part of the CALYPSO project (www.capemalta.net/calypso), conducted under the sponsorship of the EU 2007-2013 Italia-Malta Programme. This project involved the University of Malta (Physical Oceanography Unit, IOI-Malta Operational Centre, in the role of Lead partner), the University of Palermo (Lead of the Sicilian project focal point), and the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS).

The CALYPSO network is providing hourly sea surface current maps with a spatial resolution of 3 km since September 2012. These measurements, in combination with available satellite data and the wide range of physical and biological processes, make this area particularly suitable for a comparative analysis. Indeed, here we show the complementarily among HF radars data and water quality maps in determining the spatio-temporal evolution of large-scale circulation features

9239-91, Session PS

Monitoring an earthen dam using GNSS and remote sensing

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This work is based on the study of deformations of the earth dam named “Castello”, located between Bivona and Alessandria della Rocca, two towns near Agrigento, Italy.

We design a monitoring system based on three GNSS (Global Navigation Satellite System) control network installed on the earth dam providing 24 h data file; these file are daily processed together the file of some GNSS permanent stations to produce daily solution of coordinates.

The structural health monitoring has a key role in engineering applications because it allows to evaluate time changes of the structures produced by natural or human causes. With the specific objective of recognizing the occurrence of dangerous situations for people and/or things, allowing an effective alarm systems.

Deformations have been related with lake surface and volume. The former has been determined using freely available satellite data (specifically Landsat 7 SLC-Off) collected during the whole study period (DOYs 101 to 348 2011). Issues related with the filling of Product details and information about filling of the Landsat 7 SLC-off have been dealt with also using the contours line of a digital elevation model (DEM) antecedent the dam building.

This paper shows the results of a scientific collaboration between the University of Palermo, the Regional Energy and

Public Utilities Office of Sicily (Italy) and Geotop (Topcon-Sokkia Group), in which a GNSS continuous monitoring system for earth-dam deformations has been developed. The experiment was conducted on the top of the dam were three control points was placed and three GNSS permanent stations were installed. The three stations continuously transmitted data to the control centre of the Polytechnic School, University of Palermo.

Usually the conventional GNSS monitoring methods, where a base station GPS (Global Navigation System) receiver must be located near the dam, did not ensure that the accuracy of results have been independent from the displacement of the crown (top end of dam).

In this paper, a new approach in the area of study of the GNSS permanent network has been engaged to solve these problems.

The aim of this work is various: first of all, we want to evaluate whether the GNSS post processing techniques can provide static results comparable to other monitoring techniques, such as spirit leveling. The study could take a significant importance given that the Italian legislation untill today does not provide for the use of this technology within the scope of the dams or other civil engineering constructions. The use of GNSS data in structural monitoring could in fact reduce some management costs and those related to the reduction of environmental risks (landslides, floods).

Moreover, this work shows that some features of GPS technique, like 24 h data availability, are very useful in dams monitoring and the step of calculating function with a new software, entirely developed in Italy.

We also try to assess the contribution of the Department of Civil, Environmental, Aerospace and Materials (DICAM) of the University of Palermo that belong to the GNSS permanent network

in this area. The network consist of nine CORS (Continuously Operative Reference System) located in western Sicily, with an inter-distance between 22 and 80 kilometres, from each other and the Control Centre (CC) was realized at the DICAM.

To ensure high precision and accuracy a comparison of the results obtained from two scientific software (Network Deformation Analysis, NDA, Professional Edition and Bernese GNSS software, version 5.0) was showed. Field testing results show that the new GNSS approach has excellent performances. The post-processing accuracy positioning is around 1–5 mm for the deformations monitoring of the Bivona dam in Magazzolo Lake, Italy.

9239-92, Session PS

Eco-geographical analysis of desertification and desert locust infestation problem in Sudan

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Desertification and Desert locust are serious disasters that are affecting many countries worldwide. Sudan is one of the African countries that are subjected to recurrent of such disasters. International organization (UN, IFAD, and FAO) and national government bodies exert appreciable efforts to overcome this problem because of its wide distribution and adverse impact on people and environment. The aim of this study is to explore the relationship between Desert Locust infestation and desertification eco-geographical change in Sudan. The stated hypothesis is that the study area was firstly desertified and later on infested by desert locust. To verify this hypothesis desertified areas were selected from Sudan map and subjected for further investigations. Satellite images and Desert Locust ground survey data were integrated and overlaid in layers over grid of Sudan vegetation map reproduced from Harison and Jakson 1958. Information was extracted using different GIS techniques. The results showed that there are significant differences in percentages of Desert locust infestation in the vegetation zones of Sudan. In addition most of Desert locust infestation was recorded where Desertification processes occurred mainly in very low biomass areas (Desert and Semi desert eco zone) and slightly in low biomass areas (Low rainfall woodland Savanna eco zone). While no infestation recorded in high biomass areas (High rainfall woodland Savanna eco zone). The study concluded that eco-geographical changes occurred in Desert Locust infestation. As well as the desert vegetation types were expanded in to other vegetation zones. This is the case in states of Kassala, Red Sea, River Nile, Northern, Khartoum, Kordofan and Darfur State. The restoration of high biomass vegetation in these affected areas was recommended. This could be achieved by afforestation project through proper planning and carefully selection of unpalatable plants to desert locust to roll back the Desert and halt Desert Locust outbreak.

9239-94, Session PS

Evaluating the potential of GeoEye data in retrieving LAI at watershed scale

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Over the past decade, there has been a great interest in the application of Earth Observation techniques in the field of hydrology, water management and precision farming. More in particular, hydrological models for the simulation of water flow in the soil-vegetation-atmosphere system require the estimation of canopy parameters such as LAI, surface albedo, and crop height.

LAI is defined as one sided green leaf area per unit ground area in broadleaf canopies and is an important input parameter to monitor crop growth conditions and to improve the performance of crop yield models. Because direct measurements of LAI are usually time-consuming and require continuous updates, remote sensing is an alternative to estimate this attribute over large areas as watershed scale. It appears to be more capable of appreciating the long-term evolution of crop canopy or analyzing the spatial variability of heterogeneous or discontinuous canopy covers.

Two groups of techniques have been commonly applied for the estimation of the LAI from optical satellite sensor data using semi-empirical/statistical approaches (i.e., vegetation indices, VI) or physical based approaches of leaf-canopy radiative transfer model (RTM) inversion. Generally they are based on moderate spatial resolution optical sensors (with pixel sizes from 250 m to 7 km) for monitoring seasonal and inter-annual variability of LAI fields over regional to global domains (AVHRR, MODIS, SPOT VGT etc.).

Spatial and temporal coherence of LAI can be further enforced by the comparison among different sensor data considering the smallest site extent, i.e. the minimum area compatible with the resolution of the satellite product to be validated. Given objective limitations due to difficulty of on-site validation and geo-location uncertainties, these problems are minimized when a validation site is located in relatively homogeneous areas in terms of land cover type, vegetation composition and topography.

The primary objective of this work was to derive a reliable LAI estimation model from VHR satellite data to be compared with moderate resolution satellite products in order to improve LAI estimation performance for next validation activities. Due to lack of contemporaneous satellite and on-site sensor data acquisitions and intrinsic complexity of physical models, in our study case the semi-empirical approach with the CLAIR model was applied. It is based on an inverse exponential relationship between LAI and the WDVI (Weighted Difference Vegetation Index) related to different land covers.

LAI values were generated from multispectral GeoEye-1 sensor data covering a time space of 5 years (2009-2013) to study crop phenological stages on the study area of the Carapelle watershed located in the North of Puglia region (Southern Italy). Data were preliminarily pre-processed (geometric and radiometric correction), classified (ISODATA method) and

texture based analyzed in order to extract the vegetated areas (mainly cereal crops). Finally, the resulted maps were compared with moderate resolution satellite data by reaching the related correspondences.

9239-96, Session PS

Application of different quality indexes for irrigation water

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Considering the current need for implementing new irrigation systems, aiming to improve production and promote sustainable development, the objective of the present research was to characterize the physical, chemical and microbiological quality of water for irrigation, using as tools for such: quality indexes and resources from a GIS – Geographic Information System in a city in Paraná state, in which 24 family-based farms were assessed. All physical, chemical and microbiological analyses were carried out accordingly to well-known research methodologies. For the evaluation of the georeferenced data, the chosen software was the Surfer 8.0. The main results demonstrated that the evaluated indexes yielded statically similar results. The same occurred with interpolated indexes used to infer the results regarding to water quality in unsampled locations.

9239-98, Session PS

Sensitivity analysis and uncertainty in hydrosedimentological models: correlation between estimation of soil loss and scale of analysis

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Attenuate uncertainties in the results of dynamic models that estimate the sediment yield and transport in the river becomes fundamental when considering the urgency of territorials policies to minimize the risk of under-or over-exploitation of natural resources as well as indicate the water availability in watersheds. The application of simulation models of environmental processes has been widely favored by the advance of geotechnologies, in particular Geographic Information Systems, which enable the extraction, processing, analysis and integration of geospatial data. However, it is noted that little attention has been given to the analysis and evaluation of the factors responsible for the discrepancy between estimates and observations, that can be realised when the applying the model is preceded by the uncertainty analysis and sensitivity of the components terms, the so that the data obtainment and calibration of parameters are consistent with the observed reality. This paper presents to evaluate the performance of hydrosedimentological MEUPS and USLE models when applied to different scales of analysis and different methods for obtaining the topographic variables and their derivatives geomorphometric plus variation of sensitivity and uncertainty conditioned by information of the parameters involved. The watersheds of the Great Monjolo (Ipeúna-SP) and Jacutinga (Rio Claro-SP) rivers were selected for the development of this work. these areas are located in the east central region of the state of São Paulo, with rural characteristics and predominance of sandy and clay soils respectively. The activities were conducted with the theoretical scope of modeling environmental systems, and based on advanced geoprocessing and remote sensing. The results indicate that there are significant quantitative variation in the volume of soil loss when the scenarios are simulated by varying the cartographic scale adopted and dominant geomorphological characteristics of the area in study.

9239-295, Session PS

Prediction of Interdecadal variation in climate over NE China with countermeasures DUPE 9245-43

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The study shows that about 1.40C rise in mean temperature occurs between the 1900-1910s and 1980-1990s, with an abrupt change around 1990 due to climate shift. Warming, leading to extreme minimum temperature rise, smaller annual range. Analysis of the facts of climate change, We also notice that the rise is 1.60C in winter, reaching roughly 1.30C in spring, and 0.60C (0.40C) in summer (autumn). Nationwide, The most significant regional warming in Northeast China,the strongest warming is found in the northern par of NE China ,while in the boreal hemisphere the warming center of eastern Asia is in Siberia. Comparison of the temperature change in the last century over the boreal hemisphere and NE China yields that the trends and cold/warm periods are more consistent for both the regions , Respectively, the three warm periods were experienced at the beginning of the last century, 40’s, 80’s,while the cold period in between several warm periods.It is worth noting that from the 1980s to present day the climate remains to be in warming, a phenomenon that has never happened in the last century.

5-model predictions of NE China climate for the future 30-50 years indicate a higher temperature rise in the year 2030 and 2050. The yearly mean would be the 1.940C rise in 2030, with 2.06, 1.26, 1.79 and 2.660C increase in spring, summer, autumn and winter, respectively. These results suggest that the highest increase is in winter, followed by the rise in spring, autumn and summer, in order. The temperature increase is higher in the northern than in the southern part. The increase is expected to be kept in 2050, with annual mean rise of 2.420C, with the ascent of 2.13, 1.68, 2.56.and 3.210C, respectively in spring, summer, autumn and winter. The winter rise is the strongest, Followed by the autumn, spring and summer. centered on the northern part of the region. Reference to the relevant papers shows that warming centers in Siberia region.a conclusion that is similar to that derived in our study (1990) concerning the warming for the past century, which demonstrates the regional warming in future five decades would follow the law of the last century.

Based on the above findings, the cumulative temperature band of T≥100C for crop growth would be shifted northward by approximately 5 latitudes. In 2050 the original first band would move to the north of the Daxinganling mountains and the other 4 bands be nearly eliminated. The dominant farming area of rice would be shifted into the Heilongjiang valley, the winter wheat zone be expanded for experiment, the maize cropping zone should be expanded for forage and cash purpose. Climate warming is greatly beneficial to soybean crop, its high-yield band would be displaced northward, leading to its markedly increased yield, and the cultivation of chinophilous crops would be spread northward. For this purpose 6 countermeasures are proposed for the structure of staple grain crops and the necessary adjustment of their regional distribution for the stable and high yields of crops in this region.

9239-45, Session 9

Analysis of snow spatial and temporary variability through the study of terrestrial photography in the Trevelez river valley

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The spatiotemporal evolution of the snow cover may help to obtain conclusions on the variability of the atmospheric agents in high mountain areas. That evolution is difficult to

analyze due to the heterogeneity of the snow distribution on the ground. The drawback in techniques of data collection in situ and images obtained by remote sensors lies in the difficult accessibility of the area and the fixed data collection frequency, respectively. The use of terrestrial images which are georeferenced and treated to obtain snow detection is an inexpensive, and, at the same time, promising, technique capable of solving the above drawbacks due to its spatial and temporal resolution being adaptable to the problem.

This work analyzes the spatiotemporal variability of the snow in Mediterranean Mountainous areas by using terrestrial photography and the effects of scale on its modelling. The study was carried out in the river Trevélez valley, on the southern face of Sierra Nevada in southern Spain. Temporal series of images of the area were employed from September, 2011 up to May, 2013, at a frequency of 5 photographs daily taken every 2 hours from 8 a.m. onward. By georeferencing and rectifying the images, the snow pixels were identified by means of automatic detection algorithms, and the temporal variations in the snow cover with respect to its spatial distribution were determined. The maps obtained were used, on one hand, to calibrate a distributed physical snow model, and, on the other, as a direct source of data assimilation in that model. Finally, the improvement in the global simulation of the snow model when this data source was incorporated was assessed by making a comparative study of the temporal series of the snow flow measured at the gauging point with the flow obtained in the simulation.

As a result of this analysis, a temporal series of snow maps of the area with a spatial resolution of 10 x 10 m. was made. In turn, the assimilation of the data improved the simulation by up to 4% for the equivalent of water. At a watershed scale, the simulation of the flow at the control point reproduced the trend observed with a mean error of 0.406 m3/s in the value estimations. These results permit one to conclude that the methodology used is precise enough to find out the exact position of snow cover in high mountain climates, and to improve the efficiency of the model used with regard to snow simulation.

9239-46, Session 9

Drainage network extraction of Brazilian semiarid region with potential flood indication areas

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The semiarid is a region of 980 133 079 km2, located in the northeast of Brazil, comprising 1,135 counties in nine States. It is characterized by water scarcity, with periods of drought, and extreme events such as floods, caused by irregular distribution of rainfall. The study of water resources in semiarid is a priority for the government because it is a region of 23 million inhabitants, many of whom live in difficulty situations caused mainly by water scarcity. Runoff is basic information for studies involving water resources, even when it comes to groundwater. This paper proposes the extraction of surface drainage networks of the semiarid region from altimetry grids with horizontal resolutions of 30 meters (Aster GDEM) and 90 m (SRTM). A platform for developing distributed hydrological models TerraHidro will be used in the extraction of drainage. The TerraHidro employs the Priority First Search (PFS) method for the extraction of drainages with extensions created by TerraHidro developers. This method allows good drainage extraction from surface and from elevation models. A sub area of the semiarid region was used to verify the resulting drainages. The drainages of this area were manually extracted by an expert from Landsat images with horizontal resolution of 30 meters. The observation of the results shows a coincidence between the drainage manually extracted and the one by TerraHidro. To improve the visual quality of the information Rapideye images with a resolution of five meters were also used. Visual analyses of drainage extracted by TerraHidro together with satellite images allow water resource experts to perform spatial analysis within the river basin in place of punctual analysis. This assessment becomes crucial in terms of environmental water resources planning. We have concluded that TerraHidro presents results which significantly reduce the manual work in defining the drainages. The expert needs to correct only the few sites with residual errors, instead of extracting all the drainage manually. Considering a large region, such as semiarid, the use of TerraHidro is a tool that provides effective results efficiently, especially in terms of time of skilled human labor economics. After drainage extraction, a procedure called Height Above the Nearest Drainage (HAND) is used to identify potential flood areas. HAND calculates, for every cell of the regular relief grid, the relief difference between this cell and the nearest cell pertaining to the drainage network. When the relief around the drainage has a small slope, large areas can be flooded. The result can be viewed on a thematic map with differences in altitude bands, indicating areas more or less subject to flooding. The result of this work allows water resource specialists to apply their hydrological models in order to check the conditions of surface waters in semiarid employing drainage networks extracted by TerraHidro.

9239-47, Session 9

A combined remote sensing and geochemical tracing approach for localising and assessing groundwater discharge to lakes

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Groundwater discharge is recognised as major pathway for the delivery of freshwater and nutrients to lakes which both sustains water levels and supports biological communities. While the contribution of groundwater to overall water budgets may be relatively small, nutrient concentrations are often several orders of magnitude higher than in surface waters and recent studies identified groundwater inputs as a main driver of eutrophication in lakes. Consequently, groundwater inputs can have a disproportionally greater influence on water quality, particularly with respect to the determination of lake trophic status and water resource managers internationally, recognise the importance of incorporating management strategies that require quantifying groundwater fluxes into and out of lakes. However, determining in the first instance where across a water catchment groundwater discharge is occurring is an extremely challenging task, groundwater fluxes are often invisible, diffuse and highly variable both spatially and temporally.

In recognition of the significance of groundwater as a potential pollution pathway and the myriad challenges to localising and quantifying the contribution of groundwater inputs to lake waters, a robust and effective methodology to facilitate a regional scale assessment of groundwater discharges to coastal waters is evaluated in its suitability for application to lakes. The applied approach is substantiated with statistical analyses that both verify and further qualify the method as a means to localise groundwater discharge sites in lacustrine environments.

Despite the difficulties in acquiring appropriate cost- and cloud free satellite imagery and the subsequent and inevitable mismatch between satellite image acquisition and in-situ lake survey dates, the results are extremely promising. For our study area (Lough Mask Co. Mayo, Republic of Ireland) surface temperature patterns generated from four Landsat 7 ETM+ Thermal Infrared (TIR) images acquired during summer months clearly reveal large cold water plumes emanating from northern and eastern lake margins. Moreover, normalised temperature values generated from the thermal images are highly correlated with radon activity and conductivity measured across the lake during a survey in July 2012.

A simple linear regression shows that lake temperature values can explain almost 60% of the observed variability in surface radon activity while the spatial distribution of mapped residual values clearly highlights the models under-prediction at groundwater discharge hotspots. This we suggest is attributable to the more intense degassing of radon due to its

dependence on the water-air concentration gradient, higher at groundwater discharge entry points which are located in shallow lake margins.

The study demonstrates the suitability of the approach as a comprehensive and cost-effective preliminary assessment tool for localising groundwater discharge entry points for use potentially in any region where discernible temperature gradients exist between groundwater and lake waters. Evaluating the potential occurrence and understanding where groundwater discharge occurs is the first step towards more in-depth geochemical surveys that seek to clarify the role played by groundwater in lacustrine nutrient budgets.

9239-49, Session 10

A model based on satellite altimetry and imagery to evaluate water volume changes in a reservoir in Brazil

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Different satellite missions have instruments to measure the water level variation of oceans and some of these instruments are being used in continental water applications with satisfying results. Altimeters on-board the Envisat and SARAL(Altika) satellites are consistently used to measure the water level in continental water bodies. Recent studies on satellite altimetry combined with satellite imagery have shown the great potential of this technique to estimate the water volume of rivers, lakes, wetlands and reservoirs and its temporal variation in response to climate and other environmental variables. A consistent monitoring of water level variations in reservoirs is crucial to the development policies and implementation of actions regarding the distribution and use of the stored water resource. The Três Marias reservoir is located within the São Francisco river basin, known as the "national integration" river, which provides water flow to the semi-arid region of Brazil. This study presents a method to combine satellite altimetry and imagery of the lake's surface to estimate volume changes and create a model from which volume changes could be computed from either the altimetry or the lake's surface area. Our intention with this study is to evaluate the method and its precision, and the possibility to apply it in other areas, such as wetlands and other lakes where in situ measurements are not available. Landsat imagery was classified and used to establish the reservoir's surface area from different years. Altimetry data from Envisat and SARAL/Altika were obtained and compared with in situ measurements taken at the reservoir's dam. Moreover, data of monitoring stations usually have an arbitrary altitude reference and are not available for the general public; the data from the satellite altimetry has the advantage of being of global reference (geoide) and compatible with the establishment of a worldwide lake and reservoir database. We combined Envisat and SARAL/Altika altimetry data from 2007-2014 period with interpolated Landsat imagery from the same timeframe. The data was corrected using a novel processing technique resulting in a relative precision of 0.24 m (RMSE). The preliminary results of total volume change between 2007 and 2014 was 9,8028 km3.

9239-50, Session 10

Delimitation of permanent protected areas of rivers in Brazil

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Permanent Protection Area PPA, under Brazilian law, is a protected area, covered or not by native vegetation with environmental function of preserving water resources, landscape, geological stability and biodiversity, facilitate gene flow and flora, soil protection and ensure the well - being of human populations. PPA are untouchable natural areas, with strict limits of exploitation, i.e., the direct economic exploitation is not allowed. They aim to meet the fundamental right of every person to an "ecologically balanced environment" as provided in Article 225 of the Brazilian Constitution. PPA are areas from each watercourse margin of any natural perennial and intermittent watercourses and surrounding natural lakes; surrounding the artificial water reservoirs created from natural watercourses; surrounding of perennial water springs; slopes greater than 45°; salt marshes; mangroves; edges of the trays or plateaus until the break line relief; on top of hills; mountains and hills; areas where altitude exceeding 1,800 meters; footpaths in the marginal range in horizontal projection. In this paper a methodology was developed to delimit the first PPA listed, areas from each watercourse margin of any natural watercourse. This PPA is defined from the river banks regarding its width, according to the following rule: 30 meters for watercourses with up to 10 meters wide, 50m for watercourses that have 10 to 50m wide, 100m for watercourses that have 50 to 200m wide, 200m for watercourses which have from 200 to 600m wide, and 500m, to watercourses that have width greater than 600m wide. These values can be less depending on the size of the property (for small properties) and depending on the amount and size of existing public improvements on the property, such as roads, schools etc. The steps have been developed in this work that implement the proposed methodology, from watercourses represented by polygons are: building the triangular irregular network (TIN) connecting the dots forming lines each side of the river; definition of points representing the central axis of the river, called skeletonization, which consists in the junction of the center points of the triangles internal to the polygon river; trace perpendicular to the axis of the river and calculating its extension to the edge lines to obtain the width of each section; buffer that defines the extent of PPA for each river parcel that was generated according to the width of the parcel. Linking is all buffers it obtains a single polygon which defines a river PPA. After this step the size of the property and its public improvements were considered for possible reduction of PPA. Rivers and property improvements can be extracted from satellite images. In this work, properties along the Paraíba do Sul River, located in the southeastern region of Brazil, will be shown as an example of application of this methodology to find PPA. The river and possible improvements will be extracted for classification of Rapideye images of 5 meter resolution.

9239-51, Session 10

Acquisition of underwater topography in a mountain channel using terrestrial laser scanning

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More frequent, severe flood and sediment related disaster has been reported in Japan where mountains and forests make up more than 60 % of its national land. For better risk management, it is required to assimilate and forecast how the water and sediment flow in mountain channels. However, the hydraulics and hydrology of mountain channels remain less understood since heterogeneous and complex nature of mountain channel causes access and safety issues and prevents intensive and quantitative measurement. Detailed and quantitative measurement of mountain channel and stream-bed would provide valuable information for fluvial disaster management. Terrestrial Laser Scanning (TLS) is a system that has a laser scanner mounted generally on a tripod. It has been developed and mainly used in surveying, providing highly accurate 3D information of the object on the ground. As the recent advance of the technology, the application of TLS expanded to fluvial environment. In particular, green-wavelength TLS has shown promising results in acquiring underwater data at grain-scale. Our previous research, in which water depth derived by TLS and survey was compared, demonstrated good performance of green-wavelength TLS for measurement of submerged stream-bed in a steep

mountain channel with flow and complex stream-bed up to approximately 70 cm deep. The results also showed that each of water depth and flow velocity alone does not affect the accuracy of TLS measurement. Instead, it was indicated that the specification of data acquisition, that is, how to acquire TLS data may have an impact on the accuracy of derived Digital Terrain Models (DTMs). Therefore, this paper examines how the acquisition protocol of TLS affects the accuracy of data in the mountain channel. The laser data was acquired using Leica ScanStation C10 over an approximately 50 m reach of the mountain channel located in Izu Peninsula, Japan in February 2014. First, it is tested whether different scanner height, that is, incident angle affects the data acquisition in terms of point density and accuracy. Then, the difference in minimum point spacing is examined to find how much impact it has on derived DTM. It is also analysed whether a combination of multiple TLS data acquired from different direction improves data accuracy, compared to the data acquired by single measurement. Furthermore, TLS data was acquired over the step parts of the channel, where the stream-bed forms topography like steps and water flows down with foam, to examine whether TLS is capable of capturing reliable underwater data in the complex channel. All the acquired underwater data by TLS are water refraction corrected and validated using field surveyed data. The results of these tests would inform us an advantage and limitation of TLS measurement for underwater topography in the mountain channel.

9239-52, Session 11

The use of full range spectroradiometer data to assess properties of a heterogeneous soil set in a regional scale survey

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Over the last two decades, visible to near-infrared spectroscopy covering the spectral range from 0.4 to 2.5 μm has evolved into an important tool to assess soil properties quantitatively. However, the spectral assessment of soil properties is handicapped by the fact that spectral predictive mechanisms often vary from one population to another. This variability is the main reason why researchers often tend to develop only local calibration models for each field they measure with spectroscopy. For a larger geographic area in a landscape approach, heterogeneous conditions with a wide variety of combinations of spectrally active factors can typically be found. Heterogeneity, however, is one main reason for poor predictions from spectroscopic data, as an optimal calibration needs limited but sufficient set heterogeneity to represent the underlying spectral mechanisms.

For our study, the investigated plots were located in an area that covered about 600 km? in the Trier region (Rhineland-Palatinate, Germany), comprising the Hunsrück and Eifel region, the Mosel valley and also parts of Luxembourg. In this region, the variability of the geologic parent material is high with devonian slates, triassic sediments (sandstone, siltstone, limestone, dolomite, Keuper clays), conglomerates, Lias sandstone, alluvial deposits and loess. Soil types range from mainly Cambisols and Podzols to Regosols and Rendzinas to Gleysols and Fluvisols. This results in highly variable conditions for soil composition and properties.

In total, 176 soil samples were taken from the top horizon of agricultural fields and afterwards analysed in the laboratory for total organic carbon (OC), total nitrogen, hot water-extractable C and microbial C. Additionally, soil material was dried, ground and measured under laboratory conditions with a full range ASD FieldSpec-instrument.

The heterogeneity of the sample set was reflected by both the wet-chemically analysed soil parameters and the measured soil spectra. Statistical analysis like principal component analysis or cluster analysis did not reveal pronounced patterns or groupings of data. As a consequence, one “global” calibration model (with partial least squares regression PLSR, internally validated with leave-one-out cross validation) failed and led to only moderate results for all studied soil variables.

In the following we focused on two issues, which were (i) to replace the global calibration by stratified or even local calibration procedures, and (ii) to study the meaning of spectral variable selection for calibration success. For the CARS selection procedure (“competitive adaptive reweighted sampling”), the results demonstrated that more accurate estimates can be obtained using selected variables instead of the full spectrum. Spectral variable selection was also found to be helpful to detect and characterise so-called spurious correlations, which means that highly correlated variables may be estimated from spectral data if at least one of these properties is spectrally active.

9239-53, Session 11

Automatic detection and agronomic characterization of olive groves using high-resolution imagery and Lidar data

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The economic feasibility of olive growing sector in EU countries was determined by subsidies (Godini et al., 2011). As a result of the opening of the free-trade area by the Barcellona Declaration of 1995 and the EU cut in subsidies, which are expected to come into force in 2014, reorganization of the whole sector is essential if we have to ensure that Italy’s olive growing sector does not become merely picturesque or carry out an environmental protection function only (Proietti and Tombesi, 1996; Camposeo and Godini, 2010).

It can be estimated that about 25-40% of the Sicilian oliviculture must be defined as “marginal”, as they are characterized by irregular planting patterns, low tree densities, and/or a high rate of overage trees or trees affected by pathogens. Modern olive cultivation systems, on the other hand, which permit the mechanization of pruning and harvest operations are limited. Agronomists, landscape planners, policy decision-makers and other professionals have a growing need for accurate and cost-effective information on land use in general and agronomic parameters in the particular. The availability of high spatial resolution imagery has enabled researchers to propose analysis tools on agricultural parcel and tree level (Aksoy et al., 2012).

Object-oriented classifications of high-resolution panchromatic and multispectral data have been successfully applied for general land use classification (Tarantino, 2004), and for specific applications in forestry and agriculture.

Object-oriented techniques which combine the use of multispectral satellite data with other ancillary data, such as LIDAR data, are even more promising (Viñas et al., 2006; Corona, 2010; Wang et al, 2012).

In our study, we test the performance of WorldView-2 imagery relative to the detection of olive groves and the delineation of olive tree crowns, using an object-oriented approach of image classification in combined use with LIDAR data.

We selected two sites, which differ in their environmental conditions (above all in morphology) and in their agronomic parameters of olive grove cultivation. The first site has mainly a flat geomorphology, interrupted only by few valleys created by the local drainage system. The second site is characterized by a hilly and mountainous geomorphology, where often slope inclination is superior to 25%.

In the two study areas, the proposed methodology has proved to achieve the main goals of olive grove detection and tree crown delineation. The use of WorldView-2 imagery was successful, and the participation of ancillary data derived from LIDAR data and pre-processing of WorldView-2 data must be judged as very positive. The main advantage of the proposed methodology is the low necessary quantity of data input and

its automatibility. However, it should be applied in other study areas to test if the good results of accuracy assessment can be confirmed. Data extracted by the proposed methodology can be used as input data for decision-making support systems for olive grove management.

9239-54, Session 11

Accurate crop classification using hierarchical genetic fuzzy rule-based systems

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This paper investigates the effectiveness of an advanced classification system for accurate crop classification using very high resolution (VHR) satellite imagery. Specifically, a recently proposed genetic fuzzy rule-based classifier is employed, namely, the Hierarchical Rule-based Linguistic Classifier (HiRLiC). HiRLiC's model comprises a small set of simple IF-THEN fuzzy rules, easily interpretable by humans. The final classification model is constructed through an iterative procedure, where in each step a base classifier is created considering a different number of fuzzy sets per input variable. The best performing rules are inserted in the hierarchical rule base and the process is repeated again, considering a thicker granularity of the input fuzzy partition. As a result, the algorithm requires minimum user interaction, since the most important learning parameters affecting the classification accuracy are determined by the learning algorithm automatically. The system is been previously shown to be particularly well-suited for very highly-dimensional classification tasks, due to an advanced per-rule feature selection scheme incorporate in the learning algorithm.

HiRLiC is applied in a challenging crop classification task, using a SPOT5 satellite image over an intensively cultivated area near Lake Kerkini in northern Greece, which is a lake-wetland ecosystem of international ecological importance. Extensive field surveys were conducted and 1656 unique locations on the study area were visually identified and labeled into six classes: rice fields, cotton, corn, alfalfa, cereals, and non-vegetated areas. The multispectral image is initially pan-sharpened and a number of higher-order spectral and textural features are subsequently derived from the initial bands of the image. Specifically, textural information from first order statistics, gray-level co-occurrence matrices (GLCM), and local indicators of spatial association (LISA) is calculated at different scales (window sizes). Combined with advanced spectral transformations and several vegetation indices, a rich composite feature space is created for classification purposes, comprising a total of 119 features.

The results obtained prove HiRLiC's effectiveness in obtaining simple yet accurate classification rule-bases. An overall classification accuracy of 86.52% was achieved, through a model with only 13 fuzzy rules and an average of 2.77 features per rule. The observed accuracy was very close to that obtained by complex state-of-the-art classification systems, such as the support vector machines (SVM) and random forest classifiers, which resulted in classification accuracy of 88.53% and 90.74%, respectively. However, visual inspection of the derived classification maps shows that HiRLiC is characterized by higher generalization properties, providing more homogeneous classifications that the competitors. Moreover, HiRLiC offers a number of additional attractive attributes, including the inherent ability of producing fuzzy classification maps, which quantify the certainty in the classification for each class of the problem, as well as the identification of the strictly necessary features on a per-class basis. Finally, the runtime requirements for producing the thematic map was orders of magnitude lower than the respective for SVM and random forest.

9239-57, Session 11

Entropy-based noise clustering soft classification for identification of wheat crop using WorldView-2 data

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Entropy is a measure of disorderness or randomness of any system. It is low for an orderly arranged data and high for the disorderly arranged data points. For an orderly arrangement, it is easy to identify the data center because the probability of belongingness to the same information class is high. Whereas, in case of disorder arrangement, the data points are scattered randomly and hence are not good candidate for the information class center. Noise data always create problem for identifying the information class center and requires to be removed. In this study, Entropy based Noise Clustering (ENC) soft classification algorithm (Miyamoto et al., 2008) has been used for the identification of wheat crop using the high resolution WorldView-2 data. Further, to study the temporal behavior of the crop, two date WorldView-2 data were taken. Different type of Vegetation Indices (VI) viz., Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Enhanced Vegetation Index 2 (EVI2) have been used to make the temporal indices with the help of these two date datasets. Since, all the aforementioned vegetation indices formulated by the arithmetic combinations of Red and NIR reflectance of electromagnetic spectrum. Therefore, out of a total of eight spectral bands the last four spectral bands i.e. Red (630-690 nm), Red edge (705-745 nm), NIR 1 (770-895 nm) and NIR 2 (860-1040 nm) have been used to generate the possible four combinations viz. Red - NIR1, Red edge - NIR 1, Red - NIR 2 and Red edge - NIR 2, for each VI.

Furthermore, the performance of ENC method is dependent upon a parameter known as regularizing parameter (?). In this study the parameter ? has been optimized for the all temporal indices. Moreover, the entropy values have been computed from the fraction images generated from ENC classifier for all temporal indices dataset combination. It is observed that, for SR, NDVI and EVI2, the lowest value of entropy is found for 'NIR2-Red' band combination, while for SAVI, the lowest entropy is found for 'NIR1-Red' band combination. Only these lowest entropy band combinations were used for the assessment of accuracy using the Receiver Operating Characteristic (ROC) method. It is found that the SR index corresponding to the 'NIR2-Red' band combination have least entropy and highest area under the ROC curve and therefore suggesting the better identification of wheat crop in comparison to other indices, using ENC classifier.

9239-58, Session 12

A new approach for agroecosystems monitoring using high-revisit multitemporal satellite data series

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With increasing population pressure throughout the world and the need for increased agricultural production there is a definite need for improved management of the world's agricultural resources. Comprehensive, reliable and timely information on agricultural resources is necessary for the implementation of effective management decisions. In that sense, the demand for high-quality and high-frequency geo-information for monitoring of agriculture and its associated ecosystems has been growing in the recent decades. Satellite image data enable direct observation of large areas at repetitive intervals and therefore allow mapping and monitoring crops evolution. Furthermore, real time analysis can assist in making timely management decisions that affect

the outcome of the crops. The DEIMOS-1 satellite, owned and operated by ELECNOR DEIMOS Imaging (Spain), provides 22m, 3-band imagery with a very wide (620-km) swath, and has been specifically designed to produce high-frequency revisit on very large areas. This have been proved through the contracts awarded to Astrium GEO-Information Services, in 2011, 2012 and 2013, where DEIMOS-1 has provided the USDA with the bulk of the imagery used to monitor the crop season in the Lower 48, in cooperation with its twin satellite DMCii's UK-DMC2. Furthermore, high density agricultural areas have been targeted with increased frequency and analyzed in near real time to monitor tightly the evolution. In this paper we present the results obtained from a campaign carried out in 2013 with DEIMOS-1 and UK-DMC2 satellites. These campaigns provided a high-frequency revisit of target areas, with one image every two days on average: almost a ten-fold frequency improvement with respect to Landsat-8. The results clearly show the effectiveness of a high-frequency monitoring approach with high resolution images with respect to classic strategies where results are more exposed to weather conditions.

9239-59, Session 12

Change detection of land use/land cover categories in the Nile Delta region using remote sensing and GIS

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The Nile Delta region is a national issue for efficient land use/land cover at this diverse and valuable ecosystem. The Nile Delta Region is the core for a balanced economy in Egypt and a proper management is a key factor to integrate the use and maximize the benefit of its various natural resources, such as, agricultural areas, inland lakes and human resources. The continuous urbanizing activity is one of the most significant adverse changes that negatively impacted the Deltaic area in Egypt. Timely and accurate data are needed to allocate and monitor the change detection in Nile Delta regions in order to act a necessary action for regulating this catastrophic phenomenon. The objectives of this study were to utilize multi date of remotely sensed data and geographic information system (GIS) to monitor spatial and temporal changes in agricultural land use. Also, to quantify agricultural land loss this is situated in the Nile Delta. Monitoring of changes in Nile Delta was based on studying the land use and land cover in the years 1984, 2007 and 2010. The study was performed by integrating the fieldwork observations as well as satellite data of Landsat 1984, SPOT4 2007 and Egyptsat-1 2010 to assess the detection change.

The results showed the trend of changes in the arable land as cultivated areas versus non-cultivated ones. The cultivated areas were detected as 2.51M hectare and 2.48M hectare in the years 2007 and 2010 respectively which decreased by 29.4 thousand hectare. The non-cultivated areas were detected as 583880 and 6176576 hectares in the years 2007 and 2010 respectively. It was found that the main factor that affected the decrease of cultivated areas is the rapid extension of the informal settlement which was viewed as 279428 and 313489 hectares in the years 2007 and 2010 respectively. This settlement extension denatured 34060 hectares of the cultivated area loosing 11353 hectares per year. The study cleared that the urban encroachment is dominated by an informal pattern and denatured a unique alluvium, which is irrigated by a potential power of water flow "Land-River Nile Mode". This rapid extension of settlement is most probably related to population increase, as well as roads development (3%) that encouraged the urban building- up aligning these new paved roads. The study concluded that this human activities over the arable land that mostly act as an informal management is deteriorating the environmental elements in Nile Delta. The rate of this degradation will be exaggerated in a head future, if the case will be later on scanned in the same study area by more recent remote sensing data.

9239-60, Session 12

Estimating primary productivity of tropical oil palm in Malaysia using remote sensing technique and ancillary data

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The amount of carbon sequestration by vegetation can be estimated using Gross Primary Productivity (GPP) and Net Primary Productivity (NPP). GPP denotes the total carbon intake by terrestrial ecosystems while NPP is the value of GPP less the autotrophic respiration. An understanding of GPP/NPP is essential to study the role of an ecosystem in the global carbon cycle. At present, there is a knowledge gap in oil palm GPP/NPP at a regional scale. Estimating oil palm GPP/NPP at a regional scale is feasible using remote sensing data. In this study GPP and NPP of oil palm trees in Peninsular Malaysia was estimated using remote sensing based light use efficiency (LUE) model with inputs from local meteorological data, upscaled leaf area index/fractional photosynthetically active radiation (LAI/fPAR) derived using UK-DMC 2 satellite data and constant maximum LUE value (1.68 g C m-2) from the literature. NPP values estimated from the model was then compared and validated with NPP estimated using allometric equations developed by Corley and Tinker (2003), Henson (2003) and Syahrinudin (2005). Biometric data such as diameter at breast height, age and the height of the oil palm trees collected from three oil palm estates in Peninsular Malaysia were used in the allometric equations to estimate the total biomass and carbon content of oil palm trees. Annual NPP of oil palm was calculated from the difference of the total carbon one year apart in age. Results of this study show that oil palm NPP increases with respect to the age of oil palm trees, and it stabilises after ten years old. The mean value of oil palm NPP as derived using the LUE model is 1044 g C m-2 year-1 and this is 188% -273% higher than the NPP derived from the allometric equations. The estimated oil palm NPP of young oil palm trees is lower compared to mature oil palm trees (>10 years old), as young oil palm trees contribute to lower oil palm LAI and therefore fPAR, which is an important variable in the LUE model. In contrast, it is noted that oil palm NPP decreases with respect to the age of oil palm trees as estimated using the allomeric equations. It was found in this study that LUE models could not capture NPP variation of oil palm trees if LAI/fPAR is considered as an important biophysical parameter. On the other hand, it was found that tree height and DBH are important variables that can capture changes in oil palm NPP as a function of age. It is suggested in future studies that one should focus on monitoring changes in height as the canopy level monitoring efforts will be limited for oil palm trees above 10 years old. Oil palm trees grow about 50cm every year on average and so height could be used as a proxy of age and therefore variation in NPP.

9239-61, Session 12

Rice area and probable transplanting dates inventory through an enhanced remote sensing based algorithm

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Egypt faces a great challenge. Fixed water resources and increasing water demands. The agriculture sector is the main water consumer with an amount representing 83% of the available water resources (CAPMAS, 2013). The Ministry of

Water Resources and Irrigation (MWRI) is striving to satisfy the intense irrigation requirements while constrained with the limited water resources. Rice is the main water–consuming crop planted in Egypt Delta. Thus mapping of where and when rice is planted is vital. The planting occurs over a wide spatial and temporal span. Thus, rice mapping with traditional methods on a large area scale is doubtful. Elshorbagy (2013) developed an algorithm for rice mapping utilizing MODIS (MOD09A1, MOD09Q1) products where the dynamics of Land Surface Water Index (LSWI), Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) throughout the rice-planting season were combined with an arable mapping module for rice area mapping. In the present piece of work, the algorithm is further enhanced by utilizing the LANDSAT 8 imagery in the arable mapping module. Ten years of historical multi-temporal MODIS imagery (2002-2011) were analyzed applying the modified algorithm. An inventory of where and when rice was planted for each main irrigation directorate in the target period was mapped. A simple forecasting model for rice area was developed. Date windows with maximum rice transplanting were drawn. The most critical imagery dates for the algorithm to well function were identified. South-North rice transplanting lag trend was correctly mapped. The algorithm results were compared against the rice areas annual reports. The algorithm mapped results agree with the reported areas. Inter annual variation in rice areas was successfully mapped. In addition, the algorithm results conform to local planting practices. The findings of this study showed that the developed algorithm can be used for rice area and probable transplanting dates inventory mapping.

9239-62, Session 12

Regional winter wheat late freezing disaster monitoring based on phenology and MODIS land surface temperature products

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Frost injury is one of the common natural disasters for winter wheat. When winter wheat encounter low temperature in elongation stage, which tend to cause late freezing disaster. Thus, a new monitoring scheme of late frost injury has been developed based on the minimum leaf temperature and lasting days from elongation stage. For elongation stage monitoring, firstly, we establish regression statistical relationship between accumulated temperature from meteorological stations and accumulated MODIS LST from green-up to heading stage for winter wheat. Based on the green-up stage derived from time series of MODIS LAI data and accumulated MODIS LST, the starting time of elongation stage was monitored using a green-up and accumulated temperature model. Meanwhile, nighttime 8-day Aqua MODIS LST product has been used to approximately represent the minimum leaf temperature of winter wheat. Our proposed method was conducted in winter wheat planting area of Henan province from 2003 to 2011. The results show that frost damage is the most severe in the year of 2007, 2010 and 2011 with large affected acreage. It is the best in the year of 2008, 2005 and 2006 only with small acreage of mild frost. From spatially distributed late freezing map, late frost damage at the northern and western area of Henan province is the most severe; followed by the central and eastern areas; the southern area hardly has any frost damage. The frost mostly lasts for one or two days, but some regions have one week of frost damage. Besides, the area having a long time of frost almost coincides with the areas of severe frost damage in spatial-temporal distribution. The validation by the ground truth data indicates that the consistent results accounted for 80%, the heavier results accounted for 16% and the lighter results 3%. These results indicated that the proposed method has great potential for late frost monitoring. Our research provides a basic and guideline to employ remotely sensed data monitor late freezing disaster for winter wheat at the regional scale.

9239-63, Session 12

Remote sensing evaluation of ecosystem service value of gas regulation with time series Landsat images

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With the improvement of human understanding of ecosystem, more ecological service functions are paid attention and are quantitatively evaluated. The analysis of dynamic change of ecosystem service value is very significant. The remote sensing technology has been applied in the evaluation of ecosystem service value. Most of the researches were focused on the evaluation of gross ecosystem service value in large region, but involved less in the time series analysis of ecological value.

Gas regulation is one of the important ecological service functions of ecosystem. Plants transform solar energy into biotic energy through photosynthesis, fixing CO2 and releasing O2, which plays an irreplaceable role in maintaining the CO2/O2 balance and mitigating greenhouse gases emissions. The ecosystem service value of gas regulation can be evaluated from the amount of CO2 and releasing O2. Taken the net primary productivity (NPP) of ecosystem as transition parameter, the value of gas regulation service in the study could be calculated by the function as follows.

Beijing area was chosen as study area, of which the ecosystem changed rapidly. Time series LandSat images were used to monitor the change of spatial pattern of ecosystem and calculate the NPP with meteorological data in Beijing area in recent thirty years. Six ecosystems including farmland, forest, grassland, water, residential area and unused land were mapped, which had the function of gas regulation. By the above algorithms, the ecosystem service value of gas regulation in Beijing area in recent thirty years was calculated and mapped, which was used to analyze the spatial patterns and driving forces.

Results showed that the order of ecosystem service value of gas regulation in Beijing area was 1978 > 1992 > 2000 > 2010, which was consistent with the order of NPP. The contribution order for gas regulation service of six ecosystems from1978 to 2010 was basically stable. The forest and farmland played important roles of gas regulation, of which the proportion reached 80% and varied with the area from 1978 to 2010. It indicated that increasing the area of forest and farmland was helpful for enhance the ecosystem service value of gas regulation.

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9240-1, Session 1

Assimilation of AVHRR data for sea ice analysis

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A system has been developed at the Canadian Meteorological Centre (CMC) and the Canadian Ice Service (CIS) using a 3D-Var method to assimilate sea ice data from various remote sensing observations. Among them the AVHRR data is a main source for ice concentration analysis due to its high spatial resolution, high revisit frequency, and easy data acquisition. A preliminary study has indicated a potential positive impact on improving the outcome analysis accuracy, while there are still some critical issues which limit its capability and performance. The current work is to deal with these issues, which include cloud and cloud shadow contamination, image geolocation misregistration, sea ice characteristic value (CV) regional and seasonal variation, suitable forward model development, data quality control and observation error estimation, and analysis results verification. The ongoing project involves 1-year cycle (2011) of AVHRR data (NOAA-19) recorded at multiple Environment Canada ground stations at real time. It also expands to experiments over the entire domain of the North American sea ice analysis system. It aims at solving the above issues, improving the overall analysis accuracy and efficiency, and implementing the processing and assimilation of AVHRR data in a way that is feasible for eventual incorporation in the operational ice analysis system.

9240-2, Session 1

Sea-ice distribution and variability in the East Greenland Sea, 2003-13

Mauro Boccolari, Lorenzo Guerrieri, Univ. degli Studi di Modena e Reggio Emilia (Italy); Fiorigi F. Parmiggiani, Istituto di Scienze dell'Atmosfera e del Clima (Italy)

This study presents an analysis of the time series of sea-ice extent in the East Greenland Sea for the period January 2003 – December 2013. The data utilized are a subset of the Arctic Sea Ice Concentration (SIC) data set derived from the observations of the passive microwave sensors AMSR-E and AMSR-2 and produced, on a daily basis, by the Inst. of Environ. Physics (IEP) of the University of Bremen.

The area of interest goes, approximately, from 60 to 85N and from 45W to20E. On the basis of previous studies [1], the parameter Sea Ice Area (SIA) as the sum of all pixels whose SIC is above 70%, was introduced for measuring sea-ice extent. A first survey of the Greenland Sea data set showed a large anomaly in year 2012; this anomaly, clearly linked with the transition period from AMSR- E to AMSR-2 when re-sampled SSM/I data were used, was partially corrected with a linear regression procedure. The correlation between SIA variability in the annual cycle and other geophysical parameters, like air temperature and cloud cover in a longitude band limited to 45W-15W, was further investigated. A high anti-correlation between air temperature and observed ice cover is confirmed [2].

Our analysis shows that the strong decline of Arctic sea-ice extent in the last 10 years is not observed in the East Greenland Sea; this implies that large reductions have occurred in the Canadian and Russian Arctic. This result confirms an hypothesis recently postulated to explain the different sea-ice decline in the Arctic and Antarctic regions [3].

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9240-4, Session 1

First year sea ice characterization from QUAD-POL entropy/anysotropy/alpha angle classification

Eric Hudier, Univ. du Québec (Canada)

At spring when solar irradiance and air temperature cause snow and ice into an array of surface scatterers, point scatterers become the main signature of ridged environment. This information is better retained in un-filtered T3 matrixes. On another hand Lee filtered T3 matrix gives information about the diversity of a distributed target which is equally indicative of the higher variability within ridges. In order to keep both in a single set of data, we computed an hybrid matrix composed of the alpha parameter from a single look matrix and the entropy of the same matrix after a Lee 3x3 matrix. The statistics presented in the results section were computed from areas characterized as a) linear ridges, b) rubble fields, c) type 1 un-deformed ice and, d) type 2 un-deformed ice. Un-deformed type 1 ice dates back to the previous fall freeze-up period while un-deformed type 2 ice results from thinner ice formed later through the winter season in leads.

A first step toward implementing an operational extraction technique requires identifying relevant processing methods. To this end we acquired a single look complex Radarsat II Fine Beam image mid-April as a mid-day thaw followed by night time refreeze cycle had been observed on the field offshore Kuujjuarapik, Hudson Bay, Canada. Wetness measured on different locations (ridged and un-deformed ice) at the approximate time of acquisition confirmed liquid water concentrations in a range that could induce dominant surface scattering.

First a false color Pauli decomposition was generated to geo-reference test areas where field measurements were performed. The Pauli decomposition is a decomposition of the Sinclair matrix into three orthogonal matrices respectively describing single bounce backscattering, multiple bounce backscattering and volume backscattering. Different filters were applied to the composite to classify the different surfaces according to their main scattering mechanisms.

Although, the occurrence of coherent or pure scatterers is expected to be significantly higher in pressure ridges than in the rest of a sea ice image, their density is too low to draw a network of continuous lines that could be used to extract statistical data on ridges. Therefore, it is necessary to use the information obtained from distributed scatterers which themselves have distinct physical characteristics in ridges and rubble fields, most especially wetness which depends on surfaces' geometry relative to the sun. Furthermore, through incoherent decomposition of the coherency matrix, second order descriptors can be extracted to reveal dominant classes of backscattering. Figure 1 (attached), is a Wishart classification after application of a directional polarimetric Lee filter. Table I (attached) gives the statistics computed from a set of selected areas ground referenced and identified as pressure ridge, rubble field, type 1 flat ice or type 2 flat ice from a T3 matrix on which no filter, 3x3 and 7x7 Lee were applied. As can be observed, the unsupervised Wishart classifier provides stable clusters that seem to relate pretty closely to the physical characteristics of the different ice environments in our test image and increases greatly the contrast between ridged and flat areas.

9240-5, Session 2

The NASA CYGNSS mission: a pathfinder for GNSS scatterometry remote sensing applications

Randall J. Rose, Scott Gleason, Southwest Research Institute (United States); Christofer Ruf, Univ. of Michigan (United States)

Global Navigation Satellite System (GNSS) based scatterometry offers breakthrough opportunities for wave, wind, ice, and soil moisture remote sensing. Recent developments in electronics and nano-satellite technologies combined with modeling techniques developed over the past 20 years are enabling a new class of remote sensing capabilities that present more cost effective solutions to existing problems while opening new applications of Earth remote sensing. Key information about the ocean and global climate is hidden from existing space borne observatories because of the frequency band in which they operate. Using GNSS-based bi-static scatterometry performed by a constellation of micro-satellites offers remote sensing of ocean wave, wind, and ice data with unprecedented temporal resolution and spatial coverage across the full dynamic range of ocean wind speeds in all precipitating conditions.

The NASA Cyclone Global Navigation Satellite System (CYGNSS) is a space borne mission being developed to study tropical cyclone inner core processes. CYGNSS consists of 8 GPS bistatic radar receivers to be deployed on separate micro-satellites in October 2016. CYGNSS will provide data to address what are thought to be the principle deficiencies with current tropical cyclone intensity forecasts: inadequate observations and modeling of the inner core. The inadequacy in observations results from two causes: 1) Much of the inner core ocean surface is obscured from conventional remote sensing instruments by intense precipitation in the eye wall and inner rain bands. 2) The rapidly evolving (genesis and intensification) stages of the tropical cyclone life cycle are poorly sampled in time by conventional polar-orbiting, wide-swath surface wind imagers.

It is anticipated that numerous additional Earth science applications can also benefit from the cost effective high spatial and temporal sampling capabilities of GNSS remote sensing. These applications include monitoring of rough and dangerous sea states, global observations of sea ice cover and extent, meso-scale ocean circulation studies, and near surface soil moisture observations. This presentation provides a primer for GNSS based scatterometry, an overview of NASA's CYGNSS missionand its expected performance, as well as a summary of possible other GNSS based remote sensing applications.

9240-6, Session 2

Analysis of the C-band spaceborne scatterometer thermal noise

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The scatterometer is a radar designed to measure the backscatter coefficient of distributed targets. In order to compute this backscatter from the received power, the scatterometer measures also the thermal noise power in a transmission-free time window.

This noise signal is composed of two components, the receiver thermal noise and the viewed ground radiance.

The first component is instrument dependent and hence independent of the target, time and viewing geometry.

The second component is target, time and viewing geometry dependent, it is proportional to the ground target radiance.

In this paper the noise signal measured by C-band scatterometers on-board ERS-2 and Metop-A satellites is analyzed.

It was found that the noise signal carries valuable geophysical information, which is worth to be exploited.

It is shown that the noise signal varies spatially, temporally and with viewing geometry. Thus, different targets (ocean, sea ice, land) could be easily identified. A comparison was carried out between the scatterometer noise and AMSR-E radiometer brightness temperature and high correlation was found.

The noise signal processing (mainly noise substraction) is discussed, including the assessment of the Noise Equivalent Sigma Zero and the Signal-to-noise ratio. This analysis leads to a better understanding of the noise signal and its impact on the backscatter processing.

9240-7, Session 2

Analysis of the reflectance spectra of oil emulsion spilled on the sea surface

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Oil spill detection at sea using remote sensing techniques has become a common task, and is now used for monitoring of illegal discharges and accidents [Leifer12]. The characterization of the spills however remains a challenging task. Studies using airborne data have shown the interest of using hyperspectral remote sensing in the VNIR range (400 to 1000nm) for a rough estimation of thickness and evaluation of volumes at sea [Otremba04] [Lennon06], [Wettel09]. During the DeepWater Horizon oil spill, Clark and al. showed the high potential of hyperspectral data in the SWIR range (1000nm to 2500nm) for the estimation of high thicknesses ranges (up to more than a millimeter) and emulsion rates [Clark10]. The SWIR spectrum is also affected by absorption bands of the oil that can be used for the identification of oil [Lammoglia11]. Spectra of oil on water measured in the laboratory however show a complex variety of shapes and levels of reflectance. Depending on the emulsion rate, different spectral behaviors are observed when the oil thickness varies. So far, the algorithms used to estimate the key parameters have thus been based on the comparison of spectra with a spectral library, leading to the elaboration of thickness or emulsion rate maps obtained from airborne hyperspectral images [Clark10].

This paper will present a model which intends to simulate the reflectance spectra of oil on water, with the aim to use that model for the comprehension of observed spectra and further estimation of the key parameters from hyperspectral images. To establish this model, the radiative transfer equation is solved in the simple case of a homogenous layer of water bubbles in oil, overlaid on the sea water. It is assumed that the reflectance is due to three phenomena: the attenuation and the scattering in the oil layer, and the reflection on the oil-water interface. The scattering process is due to reflections on water bubbles in the oil, and modeled by the Lorenz-Mie scattering theory [Morel 73]. In order to determine an analytical solution, simplifying assumptions used in the water color studies are investigated: Single Scattering Approximation and Quasi-Single Scattering Approximation [MobleyWB], [Gordon73], [Gordon94]. The reflectance spectra computed using that model allows most of the shapes and the behavior observed on measured spectra in the laboratory with respect to the thickness and the emulsion rate to be reproduced. It also shows that the distribution of the size of the bubbles is a key parameter.

The model allows making recommendations on the manner to produce oil emulsions when elaborating a spectral library. Spectra measured during a one week weathering process in the laboratory will be presented as illustrations. Different spectral behaviors of emulsions produced with different methods will be highlighted. The spectral library elaborated using the lessons learned from the model can be used for further estimation of thickness and emulsion rates from the hyperspectral images, leading to the production of spatial maps of those key parameters.

9240-8, Session 2

Shallow water bottom mapping by lidar satellite on quasi sun synchronous orbit

Qiang Dou, Yan Zhang, Jun Zhu, Qipeng Cao, DFH Satellite Co, Ltd. (China)

Light Detection and Ranging (LiDAR) has been a kind of new technical used in space missions from 1980s especially in last 15 years. This technical processes high measurement accuracy, high resolution, powerful recognition capability and anti-interference capability. Space-Borne LiDAR which has wide field of view causes the astronautic countries more attention, and it takes an important part of global three-dimensional topography, atmosphere exploration, ocean exploration, stereo imaging and space rendezvous and docking.

This paper summarizes the laser radar detection ability which can be used on satellite and the research and development situation of the other key products. On the basis of this, a preliminary scheme using space-borne LiDAR for shallow water topography mapping is put forward. Using laser transceiver device installed on the satellite platform to transmit and receive laser pulse coaxial. The dual wavelengths (two bands including infrared and blue/green) are used to get the length from the space platform to the sea surface and bottom. With the calculation results of wave information reflected by the ocean and satellite platform position and attitude information, the depth for seabed can be accurate. LiDAR sounding can be regarded as a special dual wavelength laser altimeter system.

A kind of quasi sun synchronous orbit is designed. On this orbit, the satellite bottom point track has the characteristics of quasi 24 hours regression, and the satellite bottom point track takes a space of one satellite swath width after each interval of 24 hours. Adopts the design scheme, rapid coverage mission of the global special regions can be finished. At the end of this paper, effects of satellite attitude and orbit control precision on the measurement precision are analyzed. The attitude and orbit reasonable control requirements is put forward.

9240-9, Session 3

Bistatic scattering from a contaminated sea surface observed in C, X And Ku bands

Helmi Ghanmi, Ali Khenchaf, Fabrice Comblet, ENSTA Bretagne (France)

The aim of this paper is to study the influence of the pollutants on the electromagnetic signature of sea surface observed in bistatic configuration. Therefore, we will start the numerical analyses of the pollutants (oil slicks) effect on the characteristics of the sea surface (permittivity and spectrum). Then, we will evaluate the electromagnetic scattering coefficients of the polluted sea surface (sea surface covered by oil layer, oil emulsion) in bistatic case by using the numerical Forward-Backward Method (FBM).

In the first part of this work, we will present the impact of the pollutants (Petrol, Oil spills) on the physical and geometrical properties of the sea surface. Indeed, when the wind velocity is relatively low, the oil forms a layer up the sea surface (contaminated sea surface); in this case the pollutant damp the surface spectrum, this damping causes a reduction of the backscattering coefficients. Nevertheless, when the wind speed is high, the oil is dispersed by mixing with sea water (emulsion). In this case the oil changes the dielectric properties of sea water. As a consequence, the radar scattering coefficients will be reduced. In the second part, we will focus on the case of a sea surface covered by oil layer and polluted by oil emulsion (based on permittivity mixture measurements as function of the oil percentage in sea water). Then, we will analyze the pollutants effect on the electromagnetic scattering coefficients in bistatic case by using the numerical FBM method. The obtained numerical simulations of the electromagnetic scattering coefficients are studied as a function of various parameters: sea state, wind speed, type of pollutant (oil layer and oil emulsion), incidence and observation angles, frequencies bands (C, X and Ku) and radar polarizations. This work, will allow giving some orientation to develop new remotes methods for detection of oil spills on a sea surface.

9240-10, Session 3

Measuring marine oil spill extent by Markov Random Fields

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The Deepwater Horizon oil spill of the Gulf of Mexico in the spring of 2010 was the largest accidental marine oil spill in the history of the petroleum industry. An immediate request, after the accident, was to detect the oil slick and to measure its extent: SAR images were the obvious tool to be employed for the task.

This paper presents a processing scheme based on Markov Random Fields (MRF) theory. MRF theory describes the global information by probability terms involving local neighborhood representations of the SAR backscatter data. The random degradation introduced by speckle noise is dealt with a pre-processing stage which applies a nonlinear diffusion filter. Spatial context attributes are structured by the Bayes' equation derived from a Maximum-A_Posteriori (MAP) estimation. The probability terms define an objective function of a MRF model whose goal is to detect contours and fine structures. The markovian segmentation problem is solved with a numerical optimization method.

The scheme was applied to an Envisat/ASAR image over the Gulf of Mexico of May 9, 2010, when the oil spill was already fully developed. The final result was obtained with 40 recursion cycles, where, at each step, the segmentation consists of a 3-class label field (open sea and two oil slick thicknesses). Both the MRF model and the parameters of the stochastic optimization procedure will be provided, together with the area measurement of the two kinds of oil slick.

9240-11, Session 3

Influence of satellite alerts on the efficiency of aircraft monitoring of maritime oil pollution in German waters

Peer Helmke, Björn Baschek, Thomas Hunsänger, Susanne Kranz, Bundesanstalt für Gewässerkunde (Germany)

For detecting accidental and illegal pollution by mineral oil, the German exclusive economic zone and the coastal waters have been monitored by aircraft operationally for more than 25 years. Aircraft surveillance uses predominantly Side-Looking-Airborne-Radar (SLAR) for visualization of the effect of oil to smoothen capillary waves. A set of near range sensors complements the remote sensing data available for the human operator to classify the detected features as mineral oil, "other" or "unknown" pollution or "look-alikes".

Today, the Central Command of Maritime Emergencies (CCME) uses the operational satellite service "CleanSeaNet" provided by the European Maritime Safety Agency (EMSA): Radar satellite data is analyzed in near real time and alerts of potential pollution are sent out. Shortly after receiving the results, aircraft surveillance flights are started by the 3rd Naval Air Wing and the locations of the satellite alerts are checked. Thus, a combined system of satellite and aerial surveillance is in place. The German Federal Institute of Hydrology, BfG, has access to the data of the pollution events detected during these flights and the corresponding meta-data of flights and satellite images.

In this work, a period of several years of this data is statistically analyzed. The probability to detect pollutions are evaluated for (A) flight missions associated with satellite scenes, and (B) additional flights performed independently from satellite scenes. Thus, the influence of satellite alerts on the efficiency of aircraft monitoring is investigated. Further, numbers and trends are presented for the corresponding increase in revisit rates of the monitoring by aircraft and satellite. Finally, implications for the operational monitoring are discussed.

9240-12, Session 3

Sea slicks classification by synthetic aperture radar

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Sea pollution constitutes a threat for natural life and human activities, including fishing and tourism; important pollutant sources are industrial and sewage discharges as well as oil spills.

In this context we developed an automatic system called OSAD (Oil Spill Automatic Detector), able to discriminate oil spills (OS) from look-alikes (LA): phenomena that appear with similar features in Synthetic Aperture Radar (SAR) images. Slick detection is based on a probabilistic method that evaluate the radiometric and the geometric characteristics of the areas of interest. OSAD also provides wind field by analyzing SAR images using CMOD algorithm, based on a given relationship between wind and sea surface. When roughness is damped by a slick, the evaluated wind has no physical meaning; moreover, ships in the scene, recognizable by the high reflection signal, can also lead to false wind measurements. For this reason a procedure to remove ships has been now added: pixels having reflectance far higher than contiguous ones are neglected.

OSAD has been recently improved with new algorithms to recognize conditions of low wind, oil, biogenic and anthropogenic slicks.

After an accurate land masking and ships removal, dark areas are identified on the image and the classification methodology is applied. For every dark spot, wind is computed inside and outside the area: if outside wind value is less than a threshold of 2 m/s it is impossible to evaluate if damping is due to a slick. On the other hand, if outside wind is higher than the threshold and the difference between inside and outside the dark area is lower than 20% we consider this reduction as wind fluctuation. A wind difference higher than 20%, is interpreted as damping effect due to a slick and, therefore, the remaining dark spots are split in OS and LA with OSAD. This is done by means of a training dataset, composed by images containing both oil spills and look-alikes, established by an expert photo interpreter. LA are then analysed with a similar approach and separated in “biogenic” or “anthropogenic (non oil)” slicks. This final separation is based again on photo-interpretation of a dataset containing both natural and anthropogenic slicks with this criterion: more compact slicks are considered anthropogenic, thinner and spiral-shaped slicks are considered natural.

After classification, wind can be recalculated on SAR images by excluding slick covered areas and ships, leading to a more precise evaluation.

The system performances has been tested on C-band SAR images, in particular on images having spatial resolution so high to examine details near the coastline.

The obtained results confirm the efficiency of the algorithm in the classification of four types of surface phenomena usually found on the sea surface: the system correctly classifies more than 90% of all features.

This procedure has been implemented in OSAD also for X-band COSMO-SkyMed images, and tested with new wind evaluation algorithms found in literature.

9240-13, Session 3

On wave damping due to crude oil and oil derivates film: theory and laboratory experiment

Irina Sergievskaya, Stanislav A. Ermakov, Institute of Applied Physics (Russian Federation)

Remote sensing of organic films on the sea surface is an important problem of modern oceanography because of the need to detect pollutions and biologically productive zones in the open ocean and coastal areas. Applications of different radar and optical methods for detection of biogenic and/or anthropogenic films based on the effect of strong damping of short wind waves by surface films have been extensively studied last decades. The main disadvantage of there studies, however, was poor knowledge about physical characteristics of films responsible for the damping effect. In this paper the damping of gravity-capillary waves has been analyzed numerically and the role of physical parameters of oil films (volume viscosity, surface and interfacial tension, surface and interfacial viscosity and elasticity, and film thickness) on the value of the damping coefficient was analysed. The numerical analysis was conducted in the frame of the model of a two-layer fluid. The volume viscosities are corresponded to light and heavy oils, diesel fuel and kerosene. Two opposite cases are analysed under an assumption that the interfacial and surface viscosities or elasticity is equal to zero. The wave damping dependence on film thickness demonstrates existence of a maximum for relatively small volume viscosity values and for high values of the viscoelasticity parameter. It was confirmed that for the case when a thickness of the viscous layer is much smaller than the wavelength, the wave damping coefficient is determined only by the sum of surface and interfacial viscoelasticity parameters. The calculated damping coefficient was compared with an approximate analytical solution for thin films and possibilities of the solution use were discussed. The results have been applied to describe data of our previous laboratory experiments on wave damping due to crude oil and oil derivatives films in a wide surface wave frequency range. Physical parameters of oil and oil derivatives films were estimated when tuning the film parameters to fit theory to the experimental dependencies of the damping coefficient on film thickness. It was obtained that the crude oil films can be characterized by a complex interfacial viscoelasticity coefficient with a large real part (the film elasticity parameter), while films of diesel fuel can be characterized by a complex interfacial viscoelasticity coefficient with large imagery part (the film viscosity parameter). The surface viscoelasticity in this analysis could be neglected. The retrieved parameters do not depend on wave frequency (within the experimental error values). The peculiarity of the dispersion equation of surface waves in the presence of crude oil film obtained in our experiments - non monotonic dependence of the wave number of gravity-capillary waves on their frequency - was explained. The experiments were performed at different temperatures, and dependence of oil film physical parameters on temperature was revealed. The experiments showed that the wave damping coefficient in the presence of thin films weakly depends on temperature, while the wave damping due to thick films strongly increases when the temperature decreases because of the volume oil viscosity growth. Radar and optical contrasts of oil slicks images on the sea surface were estimated and compared with field experimental data.

9240-14, Session 3

Detecting biogenic pollution in Rybinsk Reservoir from satellite data and contact measurements

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Nature, Society and Man (Russian Federation); Dmitry M Soloviev, Marine Hydrophysical Institute (Russian Federation); Alexey Ya Strochkov, Space Research Institute (Russian Federation)

The problem of excessive algae bloom in Volga River and adjacent reservoirs has long been acknowledged. Massive algae bloom causes serious economical damage and represents a threat to water inhabitants as well as man's life and health. From ecological point of view, cyanobacteria are the most dangerous algae type. They produce toxins of neuroparalytic, protoplasmic and hemolytic action. Malodorants (geosmin) associated with dying of big biomass of cyanobacteria make water smell putrefied. Water full of cyanobacteria metabolites is allergenic, toxic and impotable.

Rybinsk Reservoir is one of the largest artificial water bodies of Russia, its surface area is 4550 km2. It sits on the upper Volga River. Mean water depth is 5,6 m with a maximum of nearly 25 m. The region is characterized by powerful winds causing strong wind waves in Rybinsk Reservoir. Its currents are wholly predetermined by wind strength and direction.

The detection of areas most affected by algae bloom using remote sensing instruments was performed based on data from the following sensors: TM Landsat-5; ETM+ Landsat-7; OLI Landsat-8; Envisat MERIS and ASAR. Landsat data were used to compile color composites and select bands whose combination provides the best detection results. Visible satellite data were found to better manifest eutrophication zones with predomination of cyanobacteria.

Envisat MERIS were used to compile suspended matter concentration charts providing rough estimates of algae content. Envisat ASAR data were compared with quasi-simultaneous visible range data. Satellite radar data, regardless their indisputable all-weather advantage, proved less informative in algae investigation as compared to optical data. There are certain algae types that produce neither a surface film nor a dense near-surface agglomeration that would attenuate gravity-capillary waves responsible for radar backscatter formation. Besides, lower backscatter (dark) areas in radar images can appear due to other reasons, first of all coastal wind shadows. Joint analysis of data obtained in different ranges (microwave and visual) gave us an understanding of which algae types were best manifested in radar images.

Contact measurements of algae properties in Rybinsk Reservoir have been performed for many years by researchers of the I.D. Papanin Inland Water Biology Institute located on its coast. They routinely perform cruises to collect water samples and determine phytoplankton content. One of the authors participated in such cruises on 24 June and 20 August 2013. Water was sampled at 6 stations, each sample was examined to derive the biomass of prevailing cyanobacteria (Aphanizomenon flos-aquae, Anabaena flos-aquae, Microsystes aureginosa, Microsystes wesenbergii). Their evolution dynamics during summer months was monitored. The results were compared with contact measurements of 2010 as well as satellite data.

Joint analysis of Landsat-7/8 and contact data gave a good correlation both for bloom areas of diatoms, which predominated in June 2013, and those of cyanobacteria, whose lifecycle peak was in late August – early September.

An attempt was made to assess the impact of wind strength on algae bloom manifestation in satellite data.

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9240-15, Session 4

Investigation of coastal zone complex MBL circulations and their potential impact on energy transport

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Since 2002, the investigators have been flying an airborne wind lidar on board a Naval Postgraduate School Twin Otter aircraft off the coast of Monterey, CA. During the most reason experiments in September 2012, the Twin Otter Doppler Wind Lidar (TODWL) flew with a Controlled Towed Vehicle (CTV) to measure the near-surface and boundary layer fluxes and winds over the coastal waters.

The TODWL flights have revealed the presence of Organized Large Eddies (OLEs) in the boundary layer that interact with and are presumably modified by coastal jets over the ocean and thermally driven flows over coastal mountains. Interactions between the topography, the coastal zone, and the atmospheric boundary layer play an important role in the evolution and structure of OLEs that contribute to mass, energy, and momentum fluxes in the boundary layer.

Investigation of the most recent flights have revealed structures in the organized Marine Boundary Layer (MBL) that we had never seen before in our lidar data until we developed new navigation and processing software. With the new software, we now see "turbulence channels" sandwiched between boundary layer rolls. These channels appear to be conduits for delivering turbulent energy to the upper part of the MBL without significant dissipation. The presence of such a vertical transport mechanism has significant implications to MBL growth models, especially parameterization of entrainment at the top of the layer.

Foster has been modifying his phenomenological model of OLEs to handle the complex MBL situations revealed by the TODWL. In particular, the lidar has revealed an interesting and likely common situation (near the California coast) where a boundary layer jet bifurcates the MBL and generates "stacked rolls"; one set bounded by the surface and the jet maximum and the other set bounded by the jet maximum and the top of the MBL.

9240-16, Session 4

Detection of seagrass scars using sparse coding and morphological filter

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Seagrasses are grass-like plants that inhabit the shallow coastal waters of some regions like Texas and Florida. They are very important component of these regions in terms of coastal ecology and economy. Seagrass meadows provide essential nursery habitats for marine fisheries, support a variety of wildlife and marine life like shrimp, crabs, wading birds, manatees, sea turtles and improve water quality. The bays have been significantly impacted over the last decades by the activities of the people who live and visit these coasts. One of the main reasons of habitat degradation is the scaring of the seagrasses, which is mainly caused by the propeller of the boats. It usually takes years to grow up again for seagrasses when propellers cut through the bottom. To reduce the scarring of seagrasses by boats, authorities started to investigate the distribution of the scarred seagrasses. One of the effective ways to track the distribution of the scarred seagrasses is remote sensing surveys.

In this study, we present a sparse coding based classification model of panchromatic image to extract the scars. Sparse coding is a recently developed machine learning technique. It has achieved state-of-the-art performances in many

applications including natural image classification, face recognition, spectral-based and spatial-spectral based HSI classification. In sparse coding, the original data is converted to a new representation by projecting it onto a set of over-completed basis functions. Each basis function contains local or low level features and is a building block for reconstruction of the original data.

The proposed method consists of four steps: 1) Dictionary learning. We constructed overlapped patches from panchromatic image to learn a set of basis functions. 2) Encoding. For each pixel in image, we projected the combined data onto the basis functions to achieve a new representation for the pixel. 3) Dimensionality reduction. The new representation usually has a very high dimensionality requiring a large amount of computational resources. We applied the l1/lq regularized multi-class logistic regression technique to reduce the dimension of the new representation. 4) Classification. In this step, we used k-nn algorithm to discriminate scars and seagrasses based on the new data representation. After classification step the final visualization of the scars was formed by employing a linear filter.

We evaluated the proposed algorithm on a part of panchromatic image of Deckle Beach, Florida. In the implementation, we first created 2480 blocks. 1330 of them are scar blocks, which center pixel belongs to a scar area, 900 of them are nonscar blocks in the sea and 250 of them are nonscar blocks in the land. The experiments were performed based on four-fold cross-validation in which three of the datasets are used as training data and the remaining one is used as the testing data in each experiment. Experimental results show that the proposed method can achieve 91.6% in terms of overall classification accuracy. We conclude that the proposed method lead to an efficient system to detect the scarred seagrasses in the shallow coastal waters by using panchromatic image.

9240-17, Session 4

Relationship between spectral reflectance and chlorophyll-a concentration in the eutrophic Lake Togo-ike

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The Lake Togo-ike is a brackish lake of the area 6.8km2, the average depth 2.8m which is located in central Tottori Prefecture of Japan. Though it is famous also as a rich production of freshwater clam, we are anxious about reduction of that production by eutrophication in recent years. Monitoring by satellites is considered as one of the monitoring methodology development for investigating the cause of eutrophication. In order to grasp the feasibility of remotely sensed chlorophyll-a concentration (Chl-a) monitoring, the objective of this study is to investigate the relationship between spectral reflectance and Chl-a in the lake. The spectral reflectance and upper-layer water sampling was performed from onboard on May 30, August 8, 2013, and March 7, 2014 at the 10 to 11 points in the lake. MS720 (EKO Ltd.) was used for spectral reflectance measurement. The wavelength range of reflectance measurement is 400 to 900 nm. Chl-a was quantified by the UNESCO method after the filtering of upper-layer water and acetone extraction in the laboratory. The range of Chl-a is 6 to 145 ?g L-1. The spectral-reflectance characteristic in the lake is the low reflectance near 670 nm (strong absorption), and the high reflectance near 700 nm (including fluorescence). Such the characteristic is the same as the eutrophic lakes such as Chesapeake Bay in the United States, or Lake Kasumigaura in Japan. A correlation analysis using the two band algorithm for Chl-a estimation was conducted using 32 obtained datasets. An optimal combination of two bands was the case of 648 nm and 700 nm (R2=0.81). However, the latest earth observation satellites are not observed at these bands. Then, the Chl-a estimation using Landsat-8 OLI bands which was launched in Feb., 2013 was examined. As a result, it became clear that the technique adapting OC3 of the operational algorithm for deriving near-surface Chl-a (O'Reilly et al. 2000) was comparatively reasonable.

9240-18, Session 4

Monitoring and predicting eutrophication of Sri Lankan inland waters using ASTER satellite data

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Inland waters serve for both economical and ecological well being; however their existence is compromised by rising eutrophication mainly due to anthropogenic activities. Traditional in-situ water quality measurements have failed to offer required temporal and spatial coverage which cope with the dynamic of water quality. Therefore, present study focused on the use of remote sensing techniques to monitor and predict eutrophication in Bolgoda Lake, Sri Lanka as a representative example of Case II waters. Lake is located at western province in an area with industries and agricultural activities. From March to December 2013, water samples at 5 points of Lake were collected once per month parallel to ASTER overpass and Chl-a of each sample was measured using a laboratory spectrophotometer. Cloud-free ASTER scenes acquired over Lake under clear sky conditions were selected during 2000 to 2013 for Chl-a estimation and trend analysis. All the ASTER images were atmospherically corrected using FLAASH and in-situ Chl-a data on Lake were regressively analyzed with atmospherically corrected three ASTER VNIR band ratios such as B1/B2 of the same date. Finally, the regression equation of the band ratio with highest correlation (B1/B2; R2 = 0.78) was used to develop algorithm for generation of 15-m resolution Chl-a distribution maps using atmospherically corrected time series satellite imageries in day by day basis. This method applied for ASTER band 1/2 ratio due to Chl-a is positively correlated with the green band reflectance and negatively correlated with the red band reflectance. Therefore, the reflectance ratio of green and red bands becomes a robust parameter to estimate the Chl-a content. According to the ASTER based Chl-a distribution maps it is clearly evident that eutrophication of the Bolgoda Lake has been gradually increased from 2005-2011. Further, results showed that there were significant eutrophic conditions throughout the year 2013 in several parts of the Lake and considerable spatial heterogeneity with higher concentrations being recorded water stagnant areas and in water adjacent to freshwater outlets. It is clear that Bolgoda Lake is apparently a disposal site of various discharges of factories in addition to poor drainage and sewage systems present in this area. Highly unplanned urbanization and absolutely lack of adequate waste disposal management facilities in industries close to Lake have resulted in pollution of water. If the present trend of waste disposal and unplanned urbanization continue, they would create enormous environmental problems in future. Results of the present study showed that information from satellite remote sensing can play a useful role in determining the changes in Chl-a related to eutrophication in Bolgoda Lake and in the development of time series Chl-a distribution maps. Such information is important for the future predictions, development and management of this area as well as in the conservation of biodiversity. Therefore we recommend incorporation with this technique for routine monitoring of water quality using multi satellite data such as ASTER in inland water bodies like Bolgoda Lake in the future.

9240-19, Session 4

Raman spectroscopy measurements of CO2 dissolved in water and CO2 bubbles for laser remote sensing in water

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Japan's sea area is twelve times larger than its land area. The effective use of the sea area is crucial for Japan as a maritime country. We are almost totally dependent on imports for our mineral and energy resources, but they are believed to be rich in Japanese seafloors, for example, minerals such as hydrothermal vents and natural gases from methane hydrates. Also, to mitigate global warming due to CO2 emission, Japanese government has been conducting verification tests on CCS (Carbon dioxide Capture and Storage) for practical use. CCS is a technology to capture CO2 separated from large-scale emission sources such as power stations and factories and store it in sediments. In such uses of the sea area, there is a need to exploit marine resources before development and monitor the environmental change as a result of the development.

Lidar (light detection and ranging) is a very promising technique for monitoring the vast seafloor. Lidar enables real-time three-dimensional (3D) imaging to measure the round-trip time between pulse emission and laser-induced signal detection, and has a number of advantages over a commonly used point sensors. The above-mentioned applications are quite tightly linked to gases. Hydrothermal fluids coming out from vents contain H2S, methane hydrate concentrates CH4, CCS stored CO2, etc. Thus, the lidar is considered to be one of the best candidates for monitoring gasses dissolved in water. For example, CO2 gas is usually detected by infrared absorption methods. However, water is a strong light absorber showing relatively high transmission only in the shorter wavelength region from UV to Green spectral range. Thus, conventional infrared absorption spectroscopy is not suited for sensing gasses in water. Therefore, we proposed Raman lidar using green laser with relatively high transmission in water.

In our previous paper, we reported on progress toward developing a technique for the underwater remote detection of CO2 dissolved in water using Raman lidar. Its effectiveness is demonstrated with remote identification of CO2 dissolved in water in a glass bottle located 20 m away from the laser source and the sensing system. This development will greatly increase the survey efficiency by 3D laser mapping for monitoring CO2 leakage sites. Although the sensitivity of the dissolved CO2 Raman lidar may not rival that of contact sensors, the efficient mapping information that lidar provides can support a sensor network.

In this work, we also examined the applicability of Raman spectroscopy as a laser remote sensing tool for monitoring gas bubbles in water. A frequency doubled Q-switched Nd:YAG laser (532 nm) was irradiated onto CO2 gas bubbles generated by an air pump. The Raman signals at 1383 cm-1 from CO2 and 1645 cm-1 from water were detected. It has been shown that the CO2/H2O Raman signals ratio is dependent on the CO2 bubble rate.

9240-20, Session 4

Shallow water surface gravity wave imaging, stereo sensing, spectra and their operational use in shallow water dredging operations and planning

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No Abstract Available.

9240-35, Session PS

Retrieval of oceanic and atmospheric parameters with FY-3B microwave radiation imager measurements

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Microwave radiation can penetrate clouds relatively unaffected by ice clouds, sensitive to a variety of geophysical parameters, and has been one of the main technologies in retrieving oceanic and atmospheric parameters. This thesis summaries the background and developments of space-borne microwave instruments in recent 40 years, introduces the progress in microwave remote sensing theory and retrieval algorithm, especially the characteristics of Microwave Radiation Imager (MWRI) flown aboard FY-3B meteorological satellite, which was developed by China independently, and described as a high-resolution, nearly all-weather meteorological instrument. Based on the microwave radiative transfer theory, this thesis simulates the brightness temperature measured by MWRI under conditions of no precipitation or ice, and a forward model for the development of the retrieval algorithm is established through comparison of the simulated results with the simultaneous satellite measurements, then establishes a multiple linear regression algorithm to retrieve the real-time global sea surface and atmospheric environmental variables with MWRI five channels, including the integrated water vapor, sea surface temperature and wind speed, and the results are compared with radiosonde observations and ocean buoy measurements. First of all, this thesis has systematically described the ocean-atmosphere microwave radiative transfer model, analyzed the sensitivity of MWRI spectral performance parameters to the precipitation and non-precipitation on the sea surface environment by using the microwave radiative transfer model, and a retrieval algorithm is proposed to simultaneously retrieve surface and atmospheric variables, including the sea surface temperature, surface wind speed, integrated water vapor, cloud liquid water path, cloud temperature, to develop a physical forward model to simulate the effects of different environmental parameters, cloud microphysical parameters and precipitation parameters on MWRI channels. Based on the simulated result, an inherent log-linear relationship between the microwave brightness temperature and variables are found, and the MWRI five channels are log-linearly combined to retrieve environmental variables. For the validation, the results are compared to the ground-based data, including radiosonde observations and ocean buoy measurements, shows that there are small differences between the retrievals and ground-based measurements during June to August in 2011. For example, the mean bias (MB) and root mean square error (RMS) between integrated water vapor retrievals and radiosonde observations are 1.54kg/m2 and 4.23kg/m2 respectively, while MB and RMS between wind, sea surface temperature retrievals and buoy observations are relatively small. Considering the contaminate effects including incidence angle and ocean wave, the FY-3B MWRI observations and its reference values in retrieving oceanic and atmospheric parameters have shown good consistency. In the near future, China will launch the next generation series of FY-3 satellite, which will onboard more advanced microwave instruments compared with those of Europe and USA, shows prosperous inspect in retrieving oceanic and atmospheric parameters. The relative achievements will provide an innovation theoretical method and technical approach for oceanic and atmospheric parameters retrieving, and build scientific fundamentals for the application of Space-borne microwave technique.

9240-38, Session PS

Influence of breaking waves on the airborne Lidar resolution

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Influence of breaking waves and whitecaps on characteristics of echo signal of airborne bathymetric lidar is investigated at strong winds. The model of echo signal, considering following factors is advanced: finite height of waves, random refraction of light by sea surface, free from foam and breaking waves, diffuse scattering of light on both sites of a surface with whitecaps on crests of waves. The account of finite height of waves is represented especially important at strong winds as in these conditions influence of whitecaps can appear essential. The relations are received, allowing estimating average delay and broadening of the signal. It is shown that whitecaps weak influence on average characteristics at wind speeds to 20 m/s. This influence appears essential in that case when measurement of a delay and, accordingly, definition of depth of a bottom or reflecting object is made by times of the first arrival of a backscattering signal from water.

9240-39, Session PS

A new method for extracting the ENSO-independent component from sea sensitive factors

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Sea Surface Temperature (SST), Sea Surface Wind (SSW), and Sea Surface Height (SSH) are sensitive factors to global change. Many models use these factors as driving forces to study global change mechanism. It is known that ENSO is close related to globe change, many factors especially SST are closely correlated to ENSO. Hence many researchers are using SST as an input parameter to represent both SST and ENSO driving effects in their models. This is not true in all the cases and using ENSO and other sensitive factors (SST, etc.) as input parameters separately may give a more attractive result. In this study, two data processing methods, named autoregressive tree method (ART) and weighted correlation coefficient (WCC) method, are introduced and used to substrate ENSO signals from those time serials sensitive factors (etc., SST, SSH, SSW). In ART method, lag ratio is calculated using correlation of time serials data of sensitive factors and ENSO index separately, then self-autoregressive tree is applied to remove ENSO related parts from sensitive factors data. In WCC method, maximum correlation coefficient between time serials sensitive factor data and ENSO index is obtained first, and weight component is dedicate selected and applied to those sensitive factors to remove ENSO related parts. The calculated correlation coefficient between the residual signal to the original one is around 0.87 for SST (significant at 99% level) which means ENSO is not the main contribution to the original signal. The result indicates that contribution of SST is not totally controlled by ENSO. Hence in globe change research, ENSO should be regarded as an independent factor similarly as those sensitive factors (SST, SSW and SSH, etc.) to be analyzed in simulation models.

9240-40, Session PS

SMOS salinity retrieval by using support vector regression with multi-angular brightness temperatures

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In November 2009 the European Space Agency's SMOS satellite was launched in order to, over ocean, enable satellite based estimations of Sea Surface Salinity (SSS) with a spatial and temporal coverage adequate for large scale oceanography [1]. For the retrieval of SSS, a maximum-likelihood Bayesian inversion scheme is applied under an iterative convergence loop [2], by comparing the multi-angular Brightness Temperatures (TBs) measured by SMOS with those gathered by a TB forward model, also taking into account constraints on Sea Surface Temperature (SST) and Wind Speed (WS). Even if the implemented iterative technique is well established and robust, it is still prone to limitations. For instance, the presence of local minima in the cost function cannot be excluded.

In this study the potential of a ?-insensitive Support Vector Regression (SVR) is tested, which instead of minimizing the observed training error attempts to minimize the generalization error bound to achieve generalized performance [3].

In [4], the SVR training/testing has been performed using in situ SSS data from the ARGO network collected in the South Pacific and in the Pacific Inter-Tropical Convergence Zone, during several sample months within the time frame of November 2010 to November 2012. SMOS measurements, either the TBs or the emissivities, at one incidence angle were used with the additional parameters SST and WS, and the performance of the SVR was evaluated considering all feature permutations. The estimated SVR salinity fields are in general (very) well correlated with ARGO data, despite that the SVR performance varies across different areas and along different months.

To extend the approach described in [4] we here include two additional regions: the Amazon plume freshwater run-off and the strong evaporation area of the oceanographic SPURS campaigns. Critical additional features which are under study are the TBs (or emissivity) acquisitions at various incidence angles with the SMOS data being binned around selected notable incidence angles to study the corresponding evolution of the SVR performances curve. Also we implement the OTT (Ocean Target Transformation) correction, used in the current SMOS inversion scheme over oceans, in order to improve results by reducing the instrumental bias.

Since the SVR is trained with the ARGO salinity values obtained at several meters depth, the SVR results are not necessarily associated to SSS giving potential to future studies focusing on the salinity gradient within the top few meters of the ocean layer, also vital for the SMOS validation activities using ARGO data.

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9240-41, Session PS

Create the ensemble sea surface temperature using Bayesian model averaging

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Many countries provide various climate variables using remote sensing through meteorological satellite products. Sea surface temperature(SST) is important climate variable for many marine application, numerical weather prediction(NWP) and

also for monitoring the global climate. So, SST is demanded to accurately detect and retrieve. But despite the same products, the represent values show differences among the satellites. Because they have uncertainty since they are retrieved through algorithm and each other algorithm have different size of uncertainty.

Studies for reducing the uncertainties of the satellite products have been steadily progressed in terms of model averaging. In ensemble forecasting, the arithmetic ensemble mean(AEM or ensemble mean) has been widely used because it provides a better result than each ensemble member. However, this approach gives no information about the uncertainties contained in the predictions. Thus, the model averaging that considers the amount of uncertainty of each model is required. Bayesian model averaging(BMA) is one of the ensemble methods to solve this problem. A probability density function(PDF) of the BMA is obtained from the weighted average of PDFs of individual ensemble members. The weights are equal to the posterior probabilities of ensemble members. The posterior probabilities are a relative predictive technique that shows the degree of similarity between the satellite product and the observation. It can be calculated by the expectation-maximization(EM) algorithm, which is a method for finding the maximum likelihood estimator. The EM algorithm is iterative and alternates between two steps: the expectation step and the maximization step.

This study focuses on generating the ensemble of satellite products by considering the differences in the uncertainty in each product based on the BMA approach. For the computation of a BMA ensemble, we used sea surface temperature(SST) because SST is an important parameter for climate change.

We calculate the BMA ensemble for the SST of several satellites including Moderate Resolution Imaging Spectroradiometer(MODIS) and Advanced Very High Resolution(AVHRR) by referencing the Advanced Along-Track Scanning Radiometer(AATSR). We compare each ensemble member, ensemble mean, ensemble median and ensemble BMA with AATSR data to verify the effects of the BMA method. It is expected that the BMA ensemble reduce the root mean square error (RMSE) and the mean bias.

9240-42, Session PS

Remote sensing and GIS for the modeling of persistent organic pollutant in the marine environment

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The characterization of the marine environment plays an important role in the understanding of the dynamics affecting the transport, fate and persistence (TFP) of Persistent Organic Pollutants (POPs).

POPs differ from others organic compounds due to their proprieties of persistence, mobility, toxicity and bioaccumulation in the environment. Contaminants reach the water compartment trough different pathways, i.e. atmospheric wet and dry deposition, atmospheric washout, transport as particulate or dissolved phase in the groundwater and rivers.

Remote sensing and Geographic Information Systems (GIS) are useful tools for costal applications. Remote sensed quantities, i.e. Chlorophyll-a (CHL-a), Chromophoric Dissolved Organic Matter (CDOM), Aerosol Optical Thickness (AOT), Sea Surface Temperature (SST) are often employed in literature for assessing the TFP of POPs. In this framework, GIS technologies allow to integrate and processing data with different spatial and temporal resolution.

This work is part of a project funded by the Ministero dell'Istruzione, dell'Università e della Ricerca.

The aim of the project is the assessment of the TFP of POPs in the Mediterranean sea. The analysis will be carried out at regional-mesoscale scale (central Mediterranean), and local spatial scale considering different test sites (the delta of the Po River and the Venice Lagoon in the north of Italy and the estuary of the Rio Nocella in the south of Italy). Moreover, a monthly, seasonal and annual time scale was chosen for the analysis.

This paper shows the first results of this study. The first step involves the implementation of GIS geodatabases for the definition of the input dataset. The geodatabases were populated with MERIS and MODIS level 2 and level 3 products of CHL-a, CDOM, AOT, Diffuse Attenuation Coefficient (DAC), Particulate Inorganic Carbon (PIC), Particulate Organic Carbon (POC) and SST.

The spatial scale (central Mediterranean sea) and the reference system have been imposed as a constraint for the geodatabases. For this purpose, all images were firstly resized on the spatial domain. Thus the reference system of the geodatabases was set to the equidistant cylindrical Plate Carrée projection.

Four geodatabases have been implemented, two for MODIS and two for MERIS products with a monthly, seasonal and climatological temporal scale. We have chosen as temporal series the years between 2002 and 2013.

Here, we present a first application of a methodology aimed to identify areas vulnerable to POPs accumulation and persistence. The implemented methodology allowed to assess the spatial distribution of the CHL-a in the central Mediterranean sea.

The chlorophyll concentration is related to the amount of nutrients in the water and therefore provides an indicator of the potential presence of POPs. Their concentration and distribution is linked to several factors, i.e. river discharges, wind conditions and sea currents.

A pilot area of 150 x 150 km located in the North Adriatic sea including the delta of the Po River and the Venice Lagoon has been initially considered. The seasonal and climatological MODIS and MERIS CHL-a variability were retrieved and compared with in-situ forcing parameters, i.e. Po River discharge rates and wind data.

Study outlooks include a better accuracy of the distribution of the vulnerable areas achieved through the use of additional parameters (CDOM, SST, POC), and an assessment of the contribution of the contaminants by atmospheric dry deposition to the marine environment.

9240-43, Session PS

Using of marine radar stations for determination of a water surface and an atmosphere near-surface layer parameters

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At present time radar methods of the seas and oceans diagnostics are actively developing. Using of the radar stations based on satellites and planes allows to receive information on a sea surface and a atmosphere near-surface layer with coverage of big water surface areas independently of day time. The developed methods of satellite radio images processing can be applied to marine radar stations. In Institute of Applied Physics works on sea surface diagnostics systems development on the basis of standard marine RLS are actively conducted. Despite smaller coverage of the territory in comparison with satellite data, marine RLS have possibility to record spatially temporary radar panoramas and to receive information on a surrounding situation quickly.

This work deals with results of the researches which were conducted within the international expedition in the Atlantic Ocean in the autumn of 2012 on a route Rotterdam (Netherlands) – Ushuaya (Argentina) – Antarctica — Ushuaya. During this expedition a complex measurements of a sea

surface, a atmosphere near-surface layer and the atmosphere parameters in the wide range of hydroweather conditions, including the storm were carried out. The system developed in IAP RAS on the basis of a marine radar I-COM MR-1200RII and the ADC block for data recording on the personal computer was used. Display of a non-uniform near-surface current on sea surface radar panoramas in storm conditions is shown. By means of the high-speed anemometer and meteorological station the measurements of the atmosphere parameters and aerodynamic drag coefficient were carried out. Comparison of the anemometer data with calculated from radar panoramas is carried out. Dependence of effective area size of an electromagnetic signal dispersion from wind speed in the wide range of wind speeds, including storm conditions is investigated. Possibility of marine RLS using for surface waves intensity and ice situation estimates also as icebergs detection is shown.

9240-45, Session PS

Comparisons of wind speed retrieval methods on C-band multi-polarization SAR measurements

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The C-band vertical-vertical (VV) polarization SAR can retrieve the wind speed by the geophysical model function (GMF) like CMOD4, CMOD_IFR2 and CMOD5.N, etc. All CMOD models used an empirical functional relation between the normalized backscatter as sensed by the spaceborne radar, wind direction relative to SAR antenna look direction and the 10 m height wind speed. As the development of radar polarization technology, multi-polarization SAR measurements can be derived including horizontal-horizontal (HH), vertical-horizontal (VH), horizontal-vertical (HV) besides VV polarization. Presently, scientists have endeavored the wind speed retrieval methods for different polarizations. RADARSAT-2 SAR fine quad-polarization imagery were the fully polarimetric SAR imagery, which gave the chance of validating the wind speed retrieval methods from multi-polarization SAR. In this paper, we made use of three kinds of polarization SAR imagery including VV, HH and VH data to compare the methods.

Firstly, 41 RADARSAT-2 SAR fine quad-polarization single look complex (SLC) data were collected. The colocated buoy wind data from in situ National Data Buoy Center (NDBC) were prepared. The VV data adopted CMOD_IFR2 and CMOD5.N GMF to retrieve wind speed. The CMOD_IFR2 was tuned for nonneutral winds but the CMOD5.N with the neutral ones. The wind direction with 180-degree ambiguity, as one input of GMF, were extracted from the wind streak spectra. The ambiguity was removed by the correlation characteristics between the VV and VH data. The Polarization Rate (PR) described the empirical relation between the VV and HH normalized backscatter. The PR was mainly dependent on incidence angles. The HH data were converted into VV data by the PR proposed by Elfouhaily to retrieve the wind speed with the same GMF as VV data. The VH normalized backscatter was independent of incidence angle and wind direction and linearly related to the wind speed. The linearity simplified the wind speed retrieval. The VH data retrieved the wind speed with the linear model proposed by Vachon. Finally, we made the comparisons between the retrieval and buoy wind. All buoy-measured wind speed at different height were converted into 10 m height. The retrieved wind direction were found to be in good agreement with buoy observations. The root mean square (Rms) error was less than 15-degree. We chose four combinations on polarization and retrieval method to validate the methods from different polarizations: 1) VV+CMOD_IFR2, which meant wind speed retrieved from VV polarization by CMOD_IFR2 model, 2) VV+CMOD5.N, 3) HH+CMOD5.N, 4) VH+linear model. In comparisons with buoy wind speed, they resulted in Rms error of 1.59 m/s, 1.87 m/s, 2.17 m/s and 1.68 m/s, respectively. It showed all of three polarizations had the capability of retrieving wind speed. We also compared the combinations each other. We found that 1) and 4) had better agreements than 2) and 3) at high wind speed. Moreover, The PR helped for HH polarization retrieve the wind speed and the VH polarization had the potential for mapping the hurricane from SAR.

9240-46, Session PS

Comparison and validation for SMOS satellite sea surface salinity measurements in South China Sea

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Ocean temperature and salinity are the two most basic variables that define the state of the ocean and they have been routinely measured since the earliest oceanographic expeditions of the 19th century. For the past 40 years, sea surface temperature (SST) has been monitored operationally from space, but until recently it was only possible to measure the salinity in-situ. Two L-band satellite missions, Soil Moisture and ocean salinity (SMOS) mission and Aquarius/SAC-D mission, aimed at observing sea surface salinity (SSS) from space have been lunched , from then on, people can obtain a roughly global map of SSS every 3 days with a nominal accuracy of 0.1psu. But in some regions, etc., South-China sea area, SSS measurement accuracy derived from SMOS is not acceptable. Thus a new SSS satellite monitoring retrieval algorithm is needed to give us a more accurate SSS products in these special regions.

To develop a suitable SSS retrieval method, calibration and validation efforts of Soil Moisture and Ocean Salinity (SMOS) sea surface salinity (SSS) measurements is crucial involving comparisons between satellite and in-situ measurements. While a local point measurement from an in-situ platform, such as Argo floats, moored and drifting buoys, CTD, etc., provides SSS estimate, a single satellite retrieval represents an average over the sensor's large footprint. Thus the presence of variability in SSS on small scales, that is, less than the footprint (150km for SMOS), may contribute to the difference between the satellite and in-situ measurements. This mismatch in their spatial coverage can affect validation accuracy in the estimation of SSS. This study quantifies the difference between in-situ and SMOS satellite SSS measurements on the basis of SSS variability in south China Sea. High resolution Hybrid Coordinate Ocean Model (HYCOM) simulation data is used to estimate the variability in SSS in South-China sea region. By separating one footprint of SMOS into around 144 small scale samples, root-mean-square difference between small scale samples (corresponding to in-situ local point) and averaged footprint SMOS estimates is calculated which represents SSS distribution pattern in South-China Sea. Maps of monthly averaged sample difference for all footprint in this region are derived which can be used in correction of spatial mismatch errors. A cruise survey and 46 moored buoys in-situ measurements in South-China Sea are organized during March to May 2012 period for SMOS SSS measurements validation purpose. A maximum difference of 0.3psu is given by 6 moored buoys in one 1x1 grid cell. Results indicate that in South-China Sea region, small-scale variability may be an important source of errors in SMOS SSS satellite measurements validation.

9240-47, Session PS

Internal waves in the Black Sea: satellite observations and in-situ measurements

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Internal waves play an important role in processes of horizontal and vertical exchange and mixing of waters, as well as in the formation of thermohaline circulation. Motions caused by internal waves have a great influence on dynamic processes in the world ocean and on its surface. Surface manifestations of internal waves are visualized in radar and optical satellite images as quasi-periodical alternating dark and bright bands: bands of smoothed ripple (slicks) generated in divergence zones of orbital currents (dark), and bands of intense ripple (rips) generated in convergence zones of the currents (bright).

Although internal waves have always drawn heightened attention of researchers, so far the most experimentally studied and theoretically described remain internal gravitational waves in the near coastal water areas of tidal seas generated due to interaction of tidal currents with the margin of the shelf.

The Black Sea is a non-tidal sea; no significant tide is ever generated there. However, surface manifestations of internal waves are often observed in satellite images, obtained over the Black Sea. Main processes responsible for the generation of internal waves in non-tidal seas are various: local fronts of up and downwelling origin in the coastal zone, upwelling relaxations, surface intrusions of fresh coastal water, internal bores and moving eddies.

The analysis of surface manifestations of internal waves involved data from Envisat ASAR and MERIS, Terra/Aqua MODIS and Landsat TM/ETM+/OLI sensors, as well as hyperspectral data from Hyperion and HICO.

There are three main areas in the Black Sea where surface manifestations are mostly observed: the north-western part of the Black Sea, near the Danube delta, near the Crimean Peninsula and the north-eastern part near Novorossiysk. The goal of our investigation is to reveal the mechanisms behind the generation of internal waves in these areas. Internal waves in the first region are observed rather regularly and are caused by surface intrusion of fresh coastal water of the Danube river. In contrast to the usual behavior of a soliton-like train of internal waves caused by river plume, the soliton trains near the Danube delta can propagate in different directions and often are involved in nonlinear interactions with each other. The type of waves (soliton or non-soliton) observed in satellite images is defined based on surface manifestations of their interactions. The correlation of the location and orientation of wave trains and fresh water fronts and the influence of eddies and fronts which accompany these internal waves are discussed.

Internal waves in the area off the coast of Crimea, in our opinion, are generated primarily by upwelling relaxations. Their characteristics were defined based on joint examination of satellite data and in-situ measurements.

Field measurements were conducted in the north-eastern part of the Black Sea from a small boat and from a scientific marine platform near the Crimean coast using CTD probes, thermistors and Acoustic Doppler Current Profilers (ADCP). The ADCP measurements at the resolution of 0.5 m allowed to detect a number of internal wave trains. Their amplitudes were estimated to reach 5-8 m. Joint analysis of satellite SAR and subsatellite data gave an assessment of their typical wavelengths at 90-100 m.

The study was completed with partial financial support from The Russian Foundation for Basic Research grants # 14-05-00520-a and 13-07-12017. Data from hyperspectrometer HICO provided by Naval Research Laboratory

9240-48, Session PS

Study on the pulse scattering from time-varying rough sea surface

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In many measuring systems, the emitted wave is usually a pulsed wave. When a laser pulse illuminates a rough object, the scattering return contains some very important information about the location of the object, physical dimension and its profile and so on which is of great significance to the target recognition, tracking and positioning and the inversion of the optical characteristics of rough surfaces. The study on the pulse scattering from rough objects, theoretically and experimentally, will be helpful to the radar system design, the feature extraction of rough objects and the culture remote sensing, its study is of considerable interest at all times.

According to the pulse wave scattering theory presented by Ishimaru, the time domain scattering field is the Fourier transformation of the frequency domain scattering field, and the correlation function of the time domain scattering field or the pulse scattering power is closely related to the two-frequency mutual coherent function, the kernel problem of the time domain scattering is to solve the two-frequency mutual coherent function of all kinds of the scattering model. Given the incident and scattered angles, mutual coherence function (MCF) is defined as the correlation of the scattered fields with two different incident frequencies. Ishimaru investigated the pulse scattering from random rough surface and discussed the pulse broadening and the enhanced backscattering effect . Wu. etc also studied the pulse scattering from rough surfaces using the two-frequency coherent function. Schertler and George derived theoretically the formulas of the two-frequency backscattering mutual correlation function from roughened sphere and roughened disk.

In the above research on the mutual coherence function, the surface was almost static and the rough distribution obeyed Gaussian. However, the rough sea surface is time-varying and non-Gaussian, the scattering property of which is different from the static Gaussian rough surface before.

This paper is to study the pulse scattering from time-varying rough sea surface with the mutual coherence function. Because of the nonlinear of the scattered field from time-domain sea surface, the characteristic function of the sea surface is expanded with Gram-Charlier series, the expanded coefficients of which will be obtained by Cox and Munk Slope probability density function. Then combing the scattering theory of Kirchhoff Approximation, the mutual coherence function of the scattering from time-varying sea surface is obtained, as well as the coherent bandwidth and the Doppler shift. Inverse Fourier translating the MCF, the pulse scattered power is then obtained. Finally, numerical results are given to analyze the influence of the different sea conditions, the dielectric constant, the width and interval of the incident pulse, as well as the incident and scattered angles on the coherent bandwidth, Doppler shift and the scattered power of the time-varying sea surface. The research will provide a theoretical basis for the remote sensing of the time-varying sea surface.

9240-49, Session PS

Radar manifestations of ship wakes in algae bloom zones

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Radar manifestations of tracks left by vessels moving in the water in areas covered by natural surface films are discussed. It is shown that these signatures can be regarded as indicators of biogenic activity and in such a way provide information useful to environmental scientists.

The experimental base of our investigation consists of radar imagery of sea surface obtained by Envisat ASAR and ERS-2 SAR. Remotely sensed data in visual and IR bands taken by sensors Landsat-8 OLI, Landsat-7 ETM+, Landsat-5 TM,

Terra/Aqua MODIS and NOAA AVHRR are involved into consideration in order to understand a comprehensive figure of meteorological and hydrodynamic processes in test areas and to facilitate the interpretation of radar imagery.

The large amount of the data available allowed us to make some generalizations and obtain statistically reliable results concerning a spatial and temporal variability of certain type of ship wake manifestations in SAR images of the sea surface.

Traditional classification of surface ship wakes manifestations in satellite SAR images specifies distinct features such as a dark trailing centreline region (turbulent wake), the Kelvin wake, narrow V-wakes aligned at some angle to the ship's path, and, sometimes, internal wave wakes generated under conditions of shallow stratification. Their characteristic lengths are reported to be up to tens of kilometers and they can exist from tens of minutes up to one hour.

Instances of radar signatures of the ship wakes dissimilar to the previously described were detected in radar images obtained in the course of a satellite monitoring campaign of the central and south-eastern Baltic which was carried out by the Space Radar Laboratory of the Space Research Institute of RAS in 2009-2012. These ship wakes can be seen in satellite radar images as a long bright strips of enhanced backscatter. Spatial and temporal characteristic of this structures are retrieved from the ASR imagery. It is revealed that characteristic length of these wakes achieves several hundred kilometres and they are also arbitrary long-living structures existing more than 5 hours.

Factors leading to formation of this type of ship wake manifestation are revealed on the base of joint analysis of satellite radar imagery and data of satellite sensors in VIS and IR bands. The hypotheses put forward of the coherence of this type of ship wakes detected in sea surface radar imagery and areas of the intensive biogenic activity where natural films are present in abundance on the sea surface under conditions of low near-surface winds.

Radar data from all passes of Envisat and ERS-2 satellites over the test areas during the monitoring period is collected and analyzed. Numerous long bright manifestations of ship wakes were identified in radar imagery. Some statistics on their seasonal, spatial and year-to-year distribution are drawn. These results are compared with temporal and spatial variations in Chlorophyll-a concentration. This parameter, representing phytoplankton biomass, can address with an adequate precision the intensity and occurrence of algal blooms. Chlorophyll-a concentration maps are used derived from satellite data as well as maps based on in situ measurements. The relation between occurrence of this type of ship wake manifestations and areas of algal blooms is established.

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9240-50, Session PS

Are the trends in the surface chlorophyll opposite between the South China Sea and the Bay of Bengal?

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Recent studies have suggested the length of the satellite records is too short to separate interannual and multidecadal cycles from climate trends. Therefore, the traditional method to assume trend being a straight line over the whole length of a time series is not suitable to reveal the actual trend of satellite Chlorophyll a concentration (Chla) records which length is less than 20 years. First, the Sen's slope and Mann-Kendall test were used to evaluate the monotonic trends in the Chla time series and the statistical significance of the trend, respectively. From the monotonic trend analysis, the significant increasing trend ($P<0.05$) in the central and southern South China Sea (SCS) and significant decreasing trend ($P<0.05$) in the Bay of Bengal (BoB) were detected. However, a time-varying trend in the surface chlorophyll between the SCS and BoB was obtained by exploring an Ensemble Empirical Mode Decomposition (EEMD) method in our study. The spatially averaged time series of regions with significant monotonic trends were decomposed into a sequence of amplitude-frequency modulated oscillatory components and a time-varying trend. Our analysis of the long term merged Chla time series from GlobColour over the time period from September 1997 to December 2011 revealed a change of trend for the central BoB before and after 2003; Chla was indeed increasing till 2003 but began to be declining since then. For the central SCS, Chla was increasing till 2006 and appears to decrease since then. The physical drivers such as wind, sea surface temperature (SST), sea surface height anomaly (SSHA) and mixed layer depth (MLD) were analyzed to investigate the internal mechanisms.

9240-51, Session PS

Analysis of the SAR hybrid-pol features relative sensitiveness for maritime target detection

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In this study, target at sea detection is addressed using Hybrid Polarity (HP) Synthetic Aperture Radar (SAR) architecture. Wave polarimetry concepts are used to define HP features that are used to observe targets at sea. The sensitivity of HP features to both targets and the surrounding environment is analyzed through some objective norms, namely the Figure-of-Merit (FoM), the sensitivity to the background variability, the dependence on sea state and target's characteristics. Experiments undertaken on HP measurements emulated from Radarsat-2 and ALOS-PALSAR full-polarimetric actual SAR data demonstrate the effectiveness of the proposed HP approach and the different sensitivity of HP features to targets and background sea characteristics. Following those results, a ranking the HP features performance is proposed which mainly highlights that HP features complement each other in the detection process. Finally, a Constant False Alarm Rate (CFAR) approach is proposed to exploit two HP features for target detection in a unsupervised way.

9240-53, Session PS

"See the Sea": Multi-user information system for investigating processes and phenomena in coastal zones via satellite remotely sensed data, particularly hyperspectral data

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The immensity and high variability of the World Ocean make the task of gathering information on processes and phenomena in it and the atmosphere above it to be rather difficult. Therefore, the importance of ocean observations by means of satellite sensors can hardly be overestimated. Currently, the application of satellite information is constantly broadening and large archives of ocean remote sensing data and related information products are being accumulated in various data centers. The obvious trend is an avalanche-like volume growth of isolated data and data products archives. It should be noted that due to fast increase of the remote sensing data flow the effective data management becomes possible only with the use of specially developed systems and technologies allowing handling vast and continuously enlarging data archives.

The functionality, main problems, main possibilities and the current state of the information system – the geoportal "See the Sea" (STS) will be reported and discussed. This system is designed and developed in IKI RAS for the investigation of various processes and phenomena in the ocean and marine

atmosphere on the base of different types of satellite remotely sensed data. The STS information system provides scientists with the possibilities to deal with the satellite remote sensing data as well as with the result of its analysis. The basic technologies are elaborated not only for creating data sets, but also for their analysis, for creation of various processes and phenomena descriptions, for managing data bases and for the use of collected scientific information in the investigation of complicated oceanic and atmospheric processes, their origination and development.

The key feature of STS is the possibility to work simultaneously with satellite information of different types and perform their joint analysis. STS provides tools for joint analysis of different types of satellite data (VIS, IR, ASAR), as well as data of ground meteorological stations, cartographic data etc.

Now, one of the fastest growing technologies in the field of ocean remote sensing is hyperspectral instrumentation. This is why the toolkit providing the ability of hyperspectral imagery analysis for studying the processes in the world ocean was launched on the basis of the “See the Sea” geoportal. The technology was created to provide automated hyperspectrometer data acquisition, geo-referencing and archiving. The specialized software developed enables hyperspectral data processing and analysis, including:

- easy to use spectral bands selection and visualization;

- assessment of the spectral bands information content;

- composition of various color syntheses;

- sequential conjugation of the information derived from different bands;

- spectral radiance and spectral reflectance graph drawing for selected spatial points;

- preparing specialized data products within specified groups of bands to provide data input for classification and analysis.

Archives for Black, Caspian and Baltic seas were populated with Hyperion and HICO imagery.

Processing and joint analysis of various satellite data were performed on the basis of the “See the Sea” geoportal. The data from different sensors (obtained by Envisat ASAR, Landsat-8 OLI, Landsat-7 ETM+, Landsat-5 TM, Terra/Aqua MODIS as well as Hyperion and HICO hyperspectral data) was analyzed jointly to study spatial and temporal variations of anthropogenic and biogenic pollution, to reveal areas of intensive algal bloom and to retrieve the detailed picture of the suspended matter distribution in the test areas of coastal zones of the Black and Baltic Seas.

Characteristics of hyperspectral instruments are compared to those of multispectral sensors and discussed from the point of view of their use for studying the processes and phenomena in the oceans and seas. Hyperspectral measurements potentially enable the extraction of more accurate spectral information when compared with multispectral measurements. Assessment of informative value of different spectral bands and their combinations for determination of hydrooptical properties of moderately turbid and productive waters of coastal zones was performed. The feasibility assessment of hyperspectral data for recognition of algal blooms areas was made. The hyperspectral data were proved also to have high level of information content in view of detection and discrimination of different types of anthropogenic and biogenic pollution in the coastal zones.

The work was partially supported by RFBR projects ##13-07-12017 ofi-m and 13-05-12093 ofi-m). HICO data was obtained under the agreement between the Naval Research Laboratory and IKI RAN.

9240-54, Session PS

Investigation of near surface wind by optical images of wind-roughened water surface

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Study of new remote sensing technique for investigation of near surface wind fields is an important oceanographic problem. This paper is focused on a new method of recording wind fields by analysis of optical images of sea surface and range – time – intensity images (RTI images) of sea surface.

An analytical model of sea surface radiance for visible light is developed taking into account polarization of light and monostatic and bistatic shadowing of surface waves for grazing view geometry. The angular distribution of sky radiance is determined by analytical model or numerical data derived during experimental measurements. Modeled sea radiance is represented as surface in coordinates grazing angle and rms (root mean square) slope.

The method of retrieval of wind speed from sea surface radiance is developed. The method consists of two stages: firstly the rms slope is determined by fitting modeled radiance with sought rms slope to measured sea surface radiance and secondly wind speed is determined using the Cox and Munk relation between mean square slope and wind speed. The precision of retrieval connected with the choice of probability distribution function (PDF) of the sea surface facet slopes and shadowing function is analyzed.

The RTI image constructed from optical profiles of sea surface is an optical analog of a side-looking radar image of sea surface. It is possible to form RTI images with range from some tens meters to tens kilometers depending on spatial resolution needed. A set of original optical devices for recoding RTI images using linear arrays of CCD-photodiodes was created. The new method of RTI images formation using multifocal set of CCD arrays permitting to increase spatial resolution and range is presented.

The investigations of near surface wind fields features in internal reservoirs and various regions of seas during last years were conducted by optical complex. The structure of near surface wind fields in ?atabatic wind flows for ranges from hundreds meters to some tens kilometers were recorded and analyzed. Derived data of optical monitoring of water surface may serve for future investigations of near surface wind features.

9240-55, Session PS

Study of the selection of indicator parameters in marine water quality evaluation and the evaluation methodology

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The content of marine water quality evaluation is to analyze the time and space distribution of water quality in accordance with the composition and content of the main materials in marine water bodies[1-2]. However, the compositions of the main materials in the water bodies are numerous. Moreover, water quality monitoring data are of years of continuous accumulation, which makes the evaluation of marine water quality difficult. There are many domestic and overseas methods about water quality evaluation, such as single factor index method [3-4], aggregative index method [4-6] and grading evaluation method [7-9] etc. in the early stage. In the recent period, the methods are fuzzy theory, grey system theory, projection pursuit and neural network [9-16] etc.. However, the above mentioned methods all utilize water quality indicators as many as possible to establish water quality evaluation model. Therefore, both the large calculated quantity and the relevance among water quality indicators influence the effect of the evaluation model. In order to discuss what the indicators which must be introduced in marine water quality evaluation are how to establish effective water quality evaluation model with limited indicators. In accordance with GB3097-1997 National Marine Water Quality Standards is, a hypothetical sample is established in this paper. Stepwise

discriminant analysis is utilized to obtain indicator parameters and the corresponding evaluation model which must be introduced to water quality evaluation.

9240-56, Session PS

Geospatial dynamics and hyperspectral data analysis for healthy detection of coral reef on the small islands, Spermonde Archipelago, Indonesia

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Remote sensing techniques provide the most valuable tool set and techniques for monitoring and mapping different bottom features in aquatic systems, such as coral reefs and sea grass. The objective of this study are to analyze of spatial dynamic of shallow water ecosystem coral reef during 40 years (1972-2012) and hyperspectral data Analysis for healthy detection on the small islands, Spermonde Archipelago, Indonesia. Spermonde Archipelago consist of over 100 small islands that have valuable marine resources and extremely rich ecosystems. The benthic communities of the Spermonde archipelago, are characterized by a high biodiversity and has a high diversity of corals, however, there has been a decrease in live coral cover and the coral diversity about 20% in the last 12 years. We used Landsat (TM and ETM +), and the acquisition are 1972, 1977, Landsat image processing are image gap fill for ETM+ image and used the software Frame and Fill, Lyzenga algorithm combined with ground truth to result a new image. Pearson correlation coefficient and cluster analysis were used to analysis of hyperspectral data and determine spectral similarity in and among coral species based on spectral responses at observed wavelengths and to examine the similarities between the categories. The benthic communities in Spermonde archipelago were as follow: live corals, dead corals covered with algae, coral rubber covered with algae, broken shell, sand, seagrass and macro algae. Several benthic communities appear to be highly correlated with one another when the entire spectrum is considered, which may lead to classification errors. Reflectance of coastal benthic communities is readily distinguishable. However some of live corals, dead corals and coral rubber a high degree of similarity in reflectance. Barrang Lompo is one of small island in Spermonde Archipelago. The spatial dymanic result shows that Barrang Lompo Island has five types coral reef based on habitat (live coral, dead coral, rubble, sand, seagrass). The coral reefs classification from 1993 to 2012 show the changes live coral and seagrass area are decrease approximately 12.45% and 8.02%, dead coral is increase 86.18%, and rubble is 68.72%. The percentage of living coral change based on the image classification in Barrang Lompo island from 1972 to 2012 has decrease and dead coral has increase from 1972 to 2012. This research will be contributed to baseline information on spatial information of small islands in Indonesia and optical characters of coastal benthic communities in tropical area. It can be used as a basic knowledge to interpretate satellite images so that they facilitate in identifying existence and differentiating some benthic communities types, especially using hyperspectral and used to make map policy on resources management of coastal waters in Indonesia.

9240-57, Session PS

An adaptive PCA fusion method for remote sensing images

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The principal component analysis (PCA) method is a popular fusion method used for its efficiency and high spatial resolution improvement. However, the spectral distortion is often found in PCA. In this paper, we propose an adaptive PCA method to enhance the spectral quality of the fused image. The amount of spatial details of the panchromatic (PAN) image injected into each band of the multi-spectral (MS) image is appropriately determined by a weighting matrix, which is defined by the edges of the PAN image, the edges of the MS image and the proportions between MS bands. In order to prove the effectiveness of the proposed method, the qualitative visual and quantitative analyses are introduced. The correlation coefficient (CC), the spectral discrepancy (SPD), and the spectral angle mapper (SAM) are used to measure the spectral quality of each fused band image. Q index is calculated to evaluate the global spectral quality of all the fused bands as a whole. The spatial quality is evaluated by the average gradient (AG) and the standard deviation (STD). Experimental results show that the proposed method improves the spectral quality very much comparing to the original PCA method while maintaining the high spatial quality of the original PCA.

9240-58, Session PS

Conceptual design of image acquisition and operation for next generation Geostationary Ocean Color Imager(GOCI-II)

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For the succession of GOCI mission, is due for completion in 2017, development of GOCI-II was started in 2012 and is scheduled to be launched in 2018. GOCI-II has two operation modes; (1) LA (Local Area) which is observation for the around of the Korean Peninsula, keep the observation from GOCI, with freely selection of the observation region in FD (Full disk) area, and (2) FD which can take images of full Earth disk around it covering a circle field of ± 60° longitude and latitude centered at the spacecraft nadir, 128.2°E. The size of LA region is same with GOCI, 2,500 km ? 2,500 km, but the GSD (Ground Sampling Distance) of LA is increased from 500 m to 250 m comparing with GOCI. The duty cycle of GOCI-II is 10 for the LA and 1 for the FD per day. The number of LA observation is also increased from 8 to 10.

GOCI-II is first observation of full Earth disk with a step-stare scanning at GEO (Geostationary Earth Orbit), using 2D detector. So the operation scenario of FD needs to be optimized. In order to significantly FD observation, solar zenith angle at the earth surface needs to be applied to the operation concept. In case of ocean remote sensing, it will keep the lower solar zenith angle and it will move from east to west with time according to the position of sun. However it will be affected by sun-glint in many slot images. In this study, we suggest the conceptual operation scenario of FD by analysis of the solar zenith angle within 80° and sun-glint within 0.01sr-1.

9240-21, Session 5

Comparison of the spatial and radiometric resolution of ERS and Metop C-band radars

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ERS-1/2 and Metop-A/B satellites carry very similar radars operating at similar frequencies (5.3/5.255 GHz) and same polarization (VV). However, the radars on-board the satellites of these two missions differ in the pulse waveform, bandwidth and slightly in geometry. Moreover, the on-board and the on-ground processing is different.

This paper investigates the spatial and radiometric resolution of these radars and a possible enhancement between ERS

(1991-2011) and Metop (2006-) missions. The spatial resolution assessment implies the computation and the comparison of the spatial response function (SRF) of both systems.

The SRF involves mainly the antenna gain pattern, the pulse waveform and the different on-board filtering stages.

The radiometric resolution depends mainly on the signal to noise ratio (SNR) and the number of independent samples (N). Thus, these two quantities are computed for each system. Furthermore, the correlation of the measurement samples in a resolution cell is computed to assess the independence. The metric used to quantify the radiometric accuracy in scatterometry is called Kp. A comparison of the Kp parameter extracted from the nominal products of the two missions to assess the expected performance based on the SNR, N and correlation analysis.

9240-22, Session 5

Analysis of internal waves around the Korean Peninsula using Radarsat-1 data

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Oceanic internal waves (IWs) are often propagated along a pycnocline where the water density changes rapidly retaining the waveform. Since microwave does not penetrate deep into water, it is not capable of directly imaging underwater phenomena, but the observed synthetic aperture radar (SAR) images are manifestation of IWs through the changes of surface roughness induced by varying surface currents associated with IWs. The process through which the roughness of the sea surface is modulated is the hydrodynamic interaction between IWs and temporally and spatially varying surface currents induced by the IWs, and this interaction can be described by the action balance equation. To interpret IWs using SAR data, the backscatter radar cross section (RCS) is computed by applying an appropriate scattering theory to the rough surface. In the present study, IWs in the waters around the Korean Peninsula are analyzed using a RADARSAT-1 C-band SAR image acquired on the 5th of July, 2000. First, the waveheight spectrum perturbed by a varying surface current field is simulated, and then RCS is computed by applying the small perturbation model (SPM) to the simulated waveheight spectrum. Since the surface current induced by IWs is a function of the wave phase velocity which depends also on the boundary layer depth of IWs, the RCS is computed by taking into account this boundary layer depth as well as the imaging geometry and SAR parameters. The computed RCS is then compared with the RADARSAT-1 SAR data, and the phase velocity and the upper layer depth of the IWs are estimated from the best-fit RCS. The estimated upper layer depth is compared with the in-situ data, yielding satisfactory results. It is expected that this study will improve our understanding of IWs by SAR remote sensing where two-dimensional field measurements of IWs are difficult to make.

9240-24, Session 5

Ship wake signatures in radar/optical images of the sea surface: observations and physical mechanisms

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It is well known that ship wakes can be clearly seen on the sea surface, in particular, in satellite radar and optical images. The structure of the wakes can strongly depend on ship characteristics, hydrometeorological characteristics, water pollutions etc. Understanding of peculiarities of ship wake signatures and physical mechanisms responsible for their formation is therefore very important to develop methods of an open ocean and coastal waters monitoring.

Spatial/temporal evolution of turbulent wakes generated by surface ships, and the surface manifestations of the wakes has been studied on the Black Sea and on the Gorky Water Reservoir. During our experiments measurements of currents in the wakes, the wake geometry, characteristics of surface films and wind waves were carried out. The currents in ship wakes were measured using an ADCP “Workhorse Sentinel” mounted on a motor boat. Sampling of surface films was conducted from the boat using small nylon nets. The collected films were reconstructed in laboratory conditions, and physical characteristics of films were studied using an original parametric wave method. In some experiments characteristics of surface waves were studied from photographs of the water surface and from data of a microwave scatterometer mounted on board a research vessel (the vessel in some experiments was used to produce the wakes). The methodology of experiments was as following: after passage of a ship of opportunity or the research vessel the wake was crossed periodically on a small motor boat approximately along the same route. Some experiments were co-located and nearly simultaneous with satellite SAR images of ship wakes in the studied area

It has been obtained that the temporal/spatial evolution of the wake width could be described approximately by a 0.4-power dependence, and the wake depth remained nearly constant at its initial stages. A simple one-dimensional model of ship wake evolution and of the wake widening has been developed using a semi-empirical theory of turbulence.

It has been shown experimentally that mean circulating currents appear near the edges of turbulent ship wakes.

The wake surface signatures are characterized by “flattening” of surface roughness due to turbulence at short distances (small “wake ages”), by formation of rough bands at the wake edges at small to intermediate stages, and finally by formation of slick bands (“rail trace”) at large ages. A physical explanation of these signatures has been done based on the action of observed mean circulating currents. Namely, the mean currents near the boundaries of the wake result in the intensification of wind waves at the edges of the wake due to a wave straining mechanism. The rough bands appeared to be strongly asymmetric when the wind direction is nearly perpendicular to the wake. Analysis of films collected from the “rail” slick bands and outside the bands when crossing the wakes has shown enhanced surfactant concentration in the slicks, a mechanism of the slick formation is suggested based on the surfactants transport to the water surface by air bubbles in the wake and on compression of thus formed surface films by the mean circulating currents.

9240-25, Session 5

Assessment of the swell impact on HY-2 SCAT wind products

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The first Chinese Ku-band scatterometer (SCAT), carrying on the microwave ocean environment satellite HY-2, has provided

the global ocean surface wind vector products since its successful launch in August 2011. The preliminary validations of HY-2 SCAT products showed encouraging results, although the negative bias of wind speed and the errors sensitivity to the wind speed are found. The inversion of HY-2 SCAT wind products is based on the geophysical model function (GMF), which empirically relates the wind field to the Ku-band radar backscatter. However, theoretical and experimental investigations indicated that the presence of swell may modify the wind stress over the ocean, and then changes the radar backscatter. Thus, the swell may influence the HY-2 SCAT wind retrieval and contribute to its product errors, because the it is not considered in the GMF. The objective of this paper is to assess the swell impact on the HY-2 SCAT wind products through the comparison of the SCAT products and the NDBC buoy observations. The products of HY-2 SCAT and NDBC buoy measurements of ocean wind and wave for a period of one year were used.

The procedures used in this work are as follows. First, in order to collocate the datasets, the temporal and spatial differences between the HY-2 SCAT and the in situ observations were limited to less than 30min and 12.5 km. Second, the buoy data processing were performed. The buoy winds were converted to the 10 m equivalent neutral winds using the coupled ocean atmosphere response experiment (COARE) bulk algorithm, in order to be comparable with HY-2 SCAT winds. For the in situ wave measurements, the directional ocean wave spectra were reconstructed from the frequency spectra and the 4 first directional distribution moments using the Maximum Entropy Method (MEM). Based upon the buoy spectra, the swell and the wind sea were separated through the wave spectra partitioning algorithm of inverted water catchment. Finally, the dependency of wind residuals between the HY-2 SCAT and the buoy measurements on the ocean wave were investigated.

Results of comparison were categorized into three groups and investigated separately through the computation of statistics of bias and scatter index (SI, which is defined as the ratio of RMSE to the mean wind speed). It is shown that the bias of the HY-2 wind speed with respect to the buoy data is -0.26 m/s, -0.49 m/s and -0.84 m/s for the case of pure swell, mixed sea and pure wind sea, respectively, with a SI of 19.37%, 16.79% and 13.12%. One can see a decreasing negative bias and an increasing scatter index (and also more dispersed in the scattered plots) with an increasing swell component. It can be inferred that the present of swell degrade the algorithm performance by the overestimating and scattering the results.

The results indicate that the swell has a significant influence on the HY-2 SCAT wind field retrieval. It is recommended that the information on sea state should be integrated into the retrieval algorithm of HY-2 SCAT wind in order to improve its accuracy.

9240-27, Session 6

Deep bathymetry changes sensed by satellite altimeters around the coastal zone of Gavdos/Crete permanent satellite calibration facility

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Over a decade, calibration values for satellite altimeters have been produced using the permanent calibration facility in Gavdos/Crete for the Jason, and recently for the SARAL/AltiKa and HY-2 missions. Several reference surfaces to represent sea levels have been chosen for this evaluation. This work outlines how changes of steep bathymetry (from 200 m to 3500 m over a distance of 10-20 km) are reflected on the determined sea surface anomalies by exhibiting variations of the order of very few centimeters on various reference surfaces during altimeter calibration. Details regarding the methodology applied for the determination of calibration values, as well as comparative results against all available reference models and surfaces will be provided.

Finally, this presentation describes the relation between calibration parameter trends and the region's local oceanographic characteristics.

9240-28, Session 6

From ENVISAT RA-2 to CRYOSAT SIRAL: validation of altimeter products near the coast (the ALCOVA Project)

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Over the last few years coastal zones have become a major focus of interest for the development of modern society. More specifically, there is an increasing need to study the factors that control coastal dynamics and to evaluate its effects on vulnerable coastlines, coastal communities, and coastal infrastructures. Among these, changes in the maximum sea level height, storm surges or surface currents are known to affect coastal processes like erosion or flooding. Satellite altimetry has proven to be a useful tool to study oceanic processes in the deep ocean; however, its use is still limited in shallow waters near the coast where two main issues still need a more detailed analysis. On one side, the local characteristics of each coastal region imply that certain corrections applied to the altimetry measurements need to be reanalysed. On the other side, the radar signal retracking algorithms need to be improved because the Brown's model, designed for deep waters, does not account for the shallow water processes occurring over continental shelves. The ESA mission ENVISAT was launched in March 2002 with a dual-frequency radar altimetry (RA-2). The satellite was operative until the end of the mission in May 2012. The ESA mission Cryosat was launched in April 2010 being still in operation. The radar instrument on-board Cryosat improves the capabilities of previous pulse-limited altimeters, such as ENVISAT RA-2. The Spanish-funded ALCOVA project aims to analyze and correct the altimetry measurements obtained from these two altimetry missions. Regarding the RA-2 data a new prototype retracker -ALES- has been developed under the frame of the ESA-DUE eSurge project aiming to improve their precision and resolution. Two pilot regions are proposed, namely, the Gulf of Cadiz and the Strait of Gibraltar in the Southwestern Iberian Peninsula. Cryosat data (in SAR mode) and the newly corrected RA-2 data (based on ALES) are being validated with available in-situ data (sea level height and significant wave height) to ensure their correct performance in the selected coastal areas.

9240-30, Session 7

Design and validation of object recognition methodologies for underwater fluorescence Lidar applications

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Light Detection And Ranging (LIDAR) has been revealed useful in several applications of remote sensing of ocean, coastal, and inland waters. LIDAR systems have been employed to provide bathymetric data for hydrographic charting and continental shelf mapping and to detect objects in the water column and on the seafloor. By equipping the LIDAR with multiple emission wavelengths and fluorescence receiver channels, a fluorescence LIDAR system is obtained that features increased potential to sound the water column and the seafloor for mapping

underwater habitats and distinguishing submerged objects and materials on the basis of their laser-induced fluorescence spectral signature. Such fluorescence LIDAR systems have been so far used mostly to detect and classify oil and other chemicals spilled in the sea as well as to discriminate among different algae and sediment species.

This work focuses on the use of submarine fluorescence LIDAR to detect and recognize objects submerged in the water column with respect to a set of objects of interest characterized by known fluorescence spectral signatures. Within this framework, the literature concerning suitable signal processing methodologies for underwater object spectral recognition is still at an early stage. In fact, extraction of object fluorescence spectral signature from the overall LIDAR signal returned from a submerged object is not trivial because the object spectral signature is obscured by its combination with water transmission and volume backscattering. In this work, signal processing methodologies to retrieve object spectral signature and subsequently perform object spectral recognition are presented and validated by means of a suitable underwater fluorescence LIDAR propagation model. The developed model describes the transmitted laser beam interaction with the underwater object, the bottom, and the water molecules. Specifically, the fluorescence return signals are modeled involving the inelastic backscattering contributions due to Raman scattering by water molecules and fluorescence by water constituents, bottom, and object.

Experimental results with simulated fluorescence LIDAR data reproducing an object submerged at different depths within the water column for several system characteristics and Case I and Case II waters show that the proposed methodologies are effective at compensating the received signal for water column effects and recognizing objects submerged in the water column.

The presented methodological approach provides great potential for automated object detection and recognition in marine and other water environments, whereas the developed underwater fluorescence LIDAR propagation model may be useful to validate and predict object recognition performance obtained with a given processing chain in specific water, system, and geometric conditions.

9240-31, Session 7

Retrieval of water optical properties using polarization of light: case I and II waters

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Light as an electromagnetic wave exhibits not only intensity and color spectrum, but also polarization properties that depend on either the source of the light or the medium in which it propagates. In atmospheric and oceanic science, polarization of natural light is modulated due to the scattering process of aerosols/hydrosols or simply molecular scattering by gases or oceanic waters. More specifically in the open ocean waters, light is highly polarized as a result of Rayleigh scattering by water molecules, whereas in more turbid coastal waters degree of polarization (DOP) is reduced due to the increase of scattering events by the hyrosols (i.e. minerals and phytoplankton particles). Therefore, in this work, we investigated using the vector radiative transfer simulation the relationship between the degree of linear polarization (DoLP) (neglecting the circular polarization) and attenuation-to-absorption coefficients ratio (c/a) of the water from which the scattering coefficient is readily computed (b = c-a) for two main types of oceanic waters (Case I & II). Case I waters resembles the open ocean clear waters where phytoplankton and color dissolved organic matter (CDOM) dominantly exist with varying concentrations. Case II waters are more optically complex due to the presences of minerals in addition to phytoplankton and CDOM and they are all independently varying in their relative concentrations. It is found the for Case I waters that only the green channels of the spectrum can be used to retrieve the scattering coefficient of the water whereas blue and red channels are dominated by the pure water effects of either Rayleigh scattering or high water absorption showing no variability between DoLP and c/a. On the other hand, Case II waters showed a strong relationship between DoLP and c/a for all wavelength of light under study (440, 550, 665 nm). Those relationships have been parameterized for both cases of waters, for all possible viewing geometry (sensor zenith and azimuth relative to the Sun's principle plane) and for varying Sun zenith angles. That relationship has been tested and validated against a dataset of in-situ measurements using a custom developed underwater polarimeter that measures the DoLP and an in-water package of instruments (WetLabs ac-s) that measure the absorption and the attenuation coefficients. Another polarimeter fixed on a platform in Long Island Sound at the LISCO station measures the DoLP of the light above water while a moored instrument package (WQM & C-star) that measures in-water optical properties have been used for a time serious validation.

9240-32, Session 7

A feasibility study of a compact fluorescence lidar for oil spills detection from UAV

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Fluorescence lidar technique is regarded as particularly valuable for the early detection and classification of oil spills on the basis of their fluorescence spectral behaviour and/or characteristic fluorescence lifetime. The technique offers also further advantages such as the detection of oil under water surface, in water-oil emulsions and also on different backgrounds (seawater, weeds, ice, etc.). Up to now, however, the deployment of fluorescence lidars for oil spill detection has been limited to conventional airborne platforms, mainly due the payload's budgets in terms of weight, consumption and dimensions. In recent years, the ever growing availability of compact and efficient laser sources and detectors provides new prospects for the design and development of very compact lidar systems deployable also from small UAV platforms.

This paper presents a feasibility study for the development of an ultra-compact fluorescence lidar to be deployed from an Unmanned Air Vehicle (UAV). The study was carried out in the frame of the ALTRO (Active Laser TransReceiver Optical) project funded by the Regione Toscana under the "Bando Unico R&D 2008" programme. The payload has been specifically designed for the detection and characterization of oil spills in natural waters and shorelines. The first step undertaken in this study was a thorough assessment of the experimental conditions and operational scenarios, completed by a set of fluorescence measurements on oil spills by means of a fluorescence lidar and an evaluation of the performance of several algorithms available in the literature for the detection and classification of oils. The second step aimed at the identification of the most suitable technologies on the market and at an evaluation of the budget constraints determined on the basis of possible UAV platforms already available for commercial use. The results of these two preliminary steps were exploited to define the measurement method, the payload technical specifications and the classification algorithms. On the basis of this analysis we finally outlined a concept design for the payload and evaluated its performances for oil spill detection in natural waters.

9240-33, Session 7

Remote estimation of in water constituents in coastal waters using neural networks

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Estimates of oceanic water constituents from satellite remote sensing reflectance (Rrs) spectra is a challenging task in coastal waters because of their complexity and consequent difficulties in devising effective retrieval algorithms. These challenges are exacerbated by difficulties of accurately obtaining water leaving radiance values in the blue spectral region because of the inadequacies of current atmospheric corrections. The work reported here is focused on the development of multiband inversion algorithms that overcomes some of these limitations. These are developed using neural networks, which use as inputs measurements at all ocean color bands of the Visible Infrared Imaging Radiometer Suite (VIIRS). They are trained on a simulated data set generated through a bio-optical model that is typical for a broad range of in water parameters. Representative distributions of the in water constituents that were used as inputs to this bio-optical model, were obtained by analyzing field observations. These distributions were now further constrained so as to eliminate unrealistic situations that are not normally observed in the field. The neural networks are trained to derive 4 inherent optical properties (IOPs) including the absorption coefficients of phytoplankton, color dissolved organic matter (CDOM) and non-algal particulates (NAP) at 443 nm as well as the particulate backscatter coefficient. Following the training process, the neural network algorithms were evaluated using several statistical indicators. This was done initially on the simulated data-set, and then extended to evaluations on field data sets from different sources, including the NASA bio-Optical Marine Algorithm Data set (NOMAD) and data from our own field campaigns in the Chesapeake Bay and Long Island Sound. These sets represent well the range of in-water optical properties and chlorophyll concentrations observed in coastal regions. The retrievals obtained with the new algorithms when applied to the NOMAD, are similar to those previously obtained and reported by us with similar neural network algorithms developed for the Moderate Resolution Imaging Spectroradiometer (MODIS). However, because of the additional, more realistic input constraints, discussed above, retrieval accuracies of phytoplankton absorption are found to be significantly improved with the new algorithms. Similar relative improvements are also observed when retrievals from the two algorithms are compared with our field data.

Finally the algorithms were applied on a satellite - in situ matched database for the Chesapeake Bay region that was created using in-situ data measured in several different locations throughout Chesapeake Bay and satellite reflectance overpass data coexisting in time and space with these in-situ measurements. As expected, algorithms applications on this data-set confirm that the 412nm MODIS band is highly erroneous in coastal waters. Better retrieval statistics are derived from satellite data when the 412nm channel is omitted or modeled rather than measured, further emphasizing the importance of improving atmospheric corrections and thereby improving water leaving radiance retrievals at this wavelength, since it is a key to improving the ability to effectively distinguish absorptions due to phytoplankton, CDOM and NAP.

9240-34, Session 7

Development of an unmanned aerial vehicle-based water quality monitoring system for inland water bodies

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A concept of an integrated water quality monitoring system based on an Unmanned Aerial Vehicle (UAV) platform is presented. The conventional methods of water quality monitoring, such as in situ sampling and remote observations from satellite or airborne sensors have their characteristic limitations and frequently do not provide sufficient information for determining the quality of water in inland lakes, estuaries or coastal areas with sufficient temporal or spatial resolution. In our work, for the first time, we propose to develop a UAV based optical remote sensing system that will perform high resolution, frequent measurements of water constituents at minimal operational overheads and therefore can be very useful for developing a comprehensive water quality monitoring program.

As the major focus of our work, we will equip a lightweight multirotor UAV with a compact optical sensor module for measuring apparent and inherent optical properties of water. From these measurements, information on different water quality parameters, such as type and concentration of phytoplanktons, CDOM and suspended solids will be derived. Within the limited payload capabilities of the UAV, the sensor module will contain a pair of spectrally high resolution micro-spectrometers to measure upwelling and downwelling irradiance above water, a light weight high definition camera to survey and instantaneously capture points of interest on the water surface and optional arrangements for studying fluorescence properties of water components with high power LEDs. Additionally, the UAV platform will have arrangements for mounting very light weight sensors for estimating physical parameters e.g. temperature, humidity, height of the UAV above water level etc. The system will be built around a low power, high speed processor along with necessary hardware and software supports for ground based control, data logging and live data streaming. To identify the geographical locations of measurement sites during a flight, high precision GPS facility will be used for waypoint navigation. Owing to the flexibility of operation and ease of adaptation for UAVs, a variety of action plans can be implemented- such as night time flight campaigns, on spot water collection, 3D image capture and water depth estimation. A critical part of the work involves optimizing the planned equipment and calibration of the sensor module components. The light weight UAVs generally allow a horizontal flight range of few hundred meters while reaching a similar height and are suited for surveying medium sized water bodies in a single flight or large area lakes in multiple flights. For successful operation of the UAV based sensing system, measurement protocols will be developed to optimize the sensing operations within a certain flight time. The capabilities of the fully developed UAV based system will be then tested during field campaigns at several Bavarian lakes and with the collected data, different water quality parameters will be quantized using existing inverse algorithms for spectral characterization. Some of the major challenges in the work lie in sensor module design and integration, safe and controlled flight operation, system optimization to detect low concentrations of water constituents and performing monitoring operations under cloud cover and night.

9240-59, Session 7

Physical oceanographic characteristics of the Azores region in the North Atlantic Ocean as observed in the DIAPICNA cruise during July/August 2011

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Within the frameworlk of EUROFLEETS funded DIAPICNA project, a ten days cruise was performed in July/August 2011 aboard R/V “Dom Carlos I” operated by the Hydrographic Institute (IH) to investigate the extent of Biological Nitrogen Fixation (BNF) in subtropical/temperate waters. The focus was in particular on the possible impact of the Azores Front/Current (AzFC) system and of deep sea iron injection by the Rainbow hydrothermal system. Thirty five CTD profiles were collected at five stations located between 31°N and 37°N latitudes in the Azores region of the North Atlantic Ocean. Each station was spaced approximately 100 km (1° latitude) starting from 32°N. Conccurently, near-real time AVISO altimetry and MODIS/AQUA satellite data were acquired to identify main surface features, mean geostrophic currents, Sea Surface Height (SSH, cm) and to derive near-surface chlorophyll a (mg m-3, as a proxy for phytoplankton biomass) and Sea Surface Temperature (SST, 0C), respectively. Results show distinct characteristics of the waters across the latitudes, and striking differences are found along the Azores Frontal/Current system at the centre, north and southern latitudes as well. Satellite imagery suggested the presence of a Mediterranean water mass eddie (MEDDIE) on station five. In situ results proved this to be right. The Deep Chlorophyll Maximum (DCM) was observed between 70 and 110 meters (as expected for sub-tropical regions). Main water masses identified in the region were the Western North Atlantic Central Water (WNACW), Eastern North Atlantic Central Water (ENACW), South Atlantic Central Water (SACW), Western Atlantic Subarctic Intermediate Water (WASIN), and Mediterranean Water (MW). The results highlight the importance of combining observational with remote sensing data to study mesoscale to large scale processes and dynamics in the open ocean.

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9241-1, Session 1

The NASA Earth Science Flight Program *(Invited Paper)*

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Earth's changing environment impacts every aspect of life on our planet and climate change has profound implications on society. Studying Earth as a single complex system is essential to understanding the causes and consequences of climate change and other global environmental concerns. NASA's Earth Science Division (ESD) shapes an interdisciplinary view of Earth, exploring interactions among the atmosphere, oceans, ice sheets, land surface interior, and life itself. This enables scientists to measure global and climate changes and to inform decisions by Government, other organizations, and people in the United States and around the world. The data collected and results generated are accessible to other agencies and organizations to improve the products and services they provide, including air quality indices, disaster prediction and response, agricultural yield projections, and aviation safety. ESD's Flight Program provides the spacebased observing systems and supporting infrastructure for mission operations and scientific data processing and distribution that support NASA's Earth science research and modeling activities. The Flight Program currently has 17 operating Earth observing space missions, including the recently launched Global Precipitation Measurement (GPM) mission and the Orbiting Carbon Observatory-2 (OCO-2). The ESD has 15 more missions planned for launch over the next decade. These include first and second tier missions from the 2007 Earth Science Decadal Survey, Climate Continuity missions to assure availability of key climate data sets, and small competitively selected orbital and instrument missions of opportunity belonging to the Earth Venture (EV) Program. The International Space Station (ISS) is being used to host a variety of NASA Earth science instruments. An overview of plans and current status will be presented.

9241-2, Session 1

Accomplishments of Aquarius: NASA's first global Sea Surface Salinity Mission; a review of the technical findings to date

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Launched 10 June 2011, the NASA's Aquarius instrument onboard the Argentine built and managed Satélite de Aplicaciones Científicas (SAC-D) has been tirelessly observing the open oceans, confirming and adding new knowledge to the not so vast measured records of our Earth's global oceans. This paper reviews the data collected over the last 3 years, it's findings, challenges and future work that is at hand for the sleepless oceanographers, hydrologists and climate scientists. Although routine data is being collected, a snapshot is presented from almost 3-years of flawless operations showing new discoveries and possibilities of lot more in the future. Repetitive calibration and validation of measurements from Aquarius continue together with comparison of the data to the existing array of Argo temperature/salinity profiling floats, measurements from the recent Salinity Processes in the Upper Ocean Regional Study (SPURS) in-situ experiment and research, and to the data collected from the European Soil Moisture Ocean Salinity (SMOS) mission. This all aids in the optimization of computer model functions to improve the basic understanding of the water cycle over the oceans and its ties to climate. The Aquarius mission operations team also has been tweaking and optimizing algorithms, reprocessing data as needed, and producing salinity movies that has never been seen before. A brief overview of the accomplishments, technical findings to date will be covered in this paper.

9241-3, Session 1

Global Precipitation Measurement (GPM) launch, commissioning, and early operations

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The Global Precipitation Measurement (GPM) mission is an international partnership co-led by NASA and the Japan Aerospace Exploration Agency (JAXA). The mission centers on the GPM Core Observatory and consists of an international network, or constellation, of additional satellites that together will provide next-generation global observations of precipitation from space. The GPM constellation will provide measurements of the intensity and variability of precipitation, three-dimensional structure of cloud and storm systems, the microphysics of ice and liquid particles within clouds, and the amount of water falling to Earth's surface. Observations from the GPM constellation, combined with land surface data, will improve weather forecast models; climate models; integrated hydrologic models of watersheds; and forecasts of hurricanes/typhoons/cylcones, landslides, floods and droughts. The GPM Core Observatory carries an advanced radar/radiometer system and serves as a reference standard to unify precipitation measurements from all satellites that fly within the constellation. The GPM Core Observatory improves upon the capabilities of its predecessor, the NASA-JAXA Tropical Rainfall Measuring Mission (TRMM), with advanced science instruments and expanded coverage of Earth's surface. The GPM Core Observatory carries two instruments, the NASA-supplied GPM Microwave Imager (GMI) and the JAXA-supplied Dual-frequency Precipitation Radar (DPR). The GMI measures the amount, size, intensity and type of precipitation, from heavy-to-moderate rain to light rain and snowfall. The DPR provides three-dimensional profiles and intensities of liquid and solid precipitation. The French Centre National d'Études Spatiales (CNES), the Indian Space Research Organisation (ISRO), the U.S. National Oceanic and Atmospheric Administration (NOAA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and the U.S. Department of Defense are partners with NASA and JAXA. The GPM Core Observatory was launched from JAXA's Tanegashima Space Center on an H-IIA launch vehicle on February 28, 2014 Japan Standard Time. The mission has completed its checkout and commissioning phase and is in early operations. The current status and early results will be discussed.

9241-4, Session 1

OCO-2 mission operations planning and initial operations experiences

Ralph R. Basilio, Harold Randy Pollock, Sarah L. Hunyadi, Jet Propulsion Lab. (United States)

OCO-2 (Orbiting Carbon Observatory-2) is the first NASA (National Aeronautics and Space Administration) mission dedicated to studying atmospheric carbon dioxide. The mission meets a science imperative by providing a critical and urgent measurement needed for better understanding of the global carbon cycle and climate change. The single instrument, consisting of three grating spectrometers, was built at the Jet Propulsion Laboratory and underwent an extensive ground test and calibration program. This was made possible through the use of a thermal vacuum chamber with a window/port that allowed optical ground support equipment to stimulate the instrument. The instrument was later delivered to Orbital Sciences Corporation for integration and test with the LEOStar-2 spacecraft bus. During this campaign, proper function and performance in environments that the observatory (instrument and spacecraft bus) will experience during launch

and ascent as well as in-flight operations was verified. OCO-2 is scheduled to launch on 01 July 2014. An initial comparison will be made between the instrument's performance on the ground and in space.

9241-5, Session 1

The Stratospheric Aerosol and Gas Experiment (SAGE III) on the International Space Station (ISS) Mission

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The Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III/ISS) mission will provide the science community with high-vertical resolution and nearly global observations of ozone, aerosols, water vapor, nitrogen dioxide, and other trace gas species in the stratosphere and upper-troposphere. SAGE III/ISS measurements will extend the long term Stratospheric Aerosol Measurement (SAM) and SAGE data record begun in the 1970s. The multi-decadal SAGE ozone and aerosol data sets have undergone intense scrutiny and are considered the international standard for accuracy and stability. SAGE data have been used to monitor the effectiveness of the Montreal Protocol. Amongst its key objectives of the mission on the space station will be to assess the state of the recovery in the distribution of ozone, to reestablish the aerosol measurements needed by both climate and ozone models, and to gain further insight into key processes contributing to ozone and aerosol variability. The space station mid-inclination orbit allows for a large range in latitude sampling and nearly continuous communications with payloads.

The SAGE III instrument is the fifth in a series of instruments developed for monitoring atmospheric constituents with high vertical resolution in the stratosphere and upper-troposphere. The SAGE III instrument is a moderate resolution spectrometer covering wavelengths from 290 nm to 1550 nm. Science data is collected in solar occultation mode, lunar occultation mode, and limb scatter measurement mode. For the space station mission, the SAGE III instrument payload includes the SAGE III Instrument Assembly, a Hexapod pointing platform provided through partnership with the European Space Agency, a miniature inertial measurement unit, a contamination-monitoring package, and an Interface Adapter Module mounted to an ExPRESS Pallet Adapter.

Access to space is provided via an International Space Station program SpaceX Falcon 9 launch vehicle. Mounted in the unpressurized section of the Dragon trunk, SAGE III will be robotically removed from the Dragon and installed on the space station using an ExPRESS Pallet Adapter. SAGE III/ISS will be mounted to the ExPRESS Logistics Carrier 4 on the starboard side of the station. To facilitate a nadir view from this location, a Nadir Viewing Platform payload was developed which mounts between the carrier and the SAGE III Instrument Payload.

9241-6, Session 2

ICESat-2: the next generation satellite for altimetric measurements of the Earth's surface

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Understanding the causes and magnitude of change in the cryosphere remains a priority for earth science research. Over the past decade, NASA earth observing satellites have documented a decrease in both the extent and thickness of Arctic sea ice, and ongoing loss of grounded ice from the Greenland and Antarctic ice sheets. Understanding the pace and mechanisms of these changes requires long-term observations of ice sheet mass, sea ice thickness and sea ice extent.

As a result of the success of NASA's ICESat mission (2003-2009), the Earth Science Decadal Survey of the National Research Council (NRC) recommended a follow-on mission to continue these observations. In response, NASA tasked Goddard Space Flight Center in February 2008 with the development and deployment of what has become the ICESat-2 mission, now scheduled for launch in 2017. The primary goals of the ICESat-2 mission are consistent with the direction provided by the NRC: deploy a spaceborne sensor to collect altimetry data of the Earth's surface optimized to measure ice sheet elevation change and sea ice thickness, while also generating an estimate of global vegetation biomass. As a result of this direction, the ICESat-2 science definition team developed the following four science objectives

• Quantify polar ice-sheet contributions to current and recent sea-level change and the linkages to climate conditions

• Quantify regional signatures of ice-sheet changes to assess mechanisms driving those changes and improve predictive ice sheet models; this includes quantifying the regional evolution of ice sheet change, such as how changes at outlet glacier termini propagate inward.

• Estimate sea-ice thickness to examine ice/ocean/atmosphere exchanges of energy, mass and moisture;

• Measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change.

The ICESat-2 mission will collect these observations using a laser based altimeter system to measure the elevation of glaciers ice sheets, and how these elevations change through time, by observing the same tracks over the ice sheets 4 times each year. Over sea-ice covered areas, the mission will distinguish between the height of ocean surface, and the height of the sea ice to determine the sea ice thickness as the density differences between ocean water and sea ice are well-known. In the mid-latitudes, ICESat-2 will measure both the elevation of the earth's surface, and the elevation of the top of the tree canopy to enable estimates of global vegetation canopy height.

System Overview

For mission definition and formulation purposes, the ICESat-2 mission is defined at the highest level in terms of three segments - the Space Segment, Ground Segment, and the Launch Support Segment

The space segment of ICESat-2 consists of the observatory, and the single instrument on that observatory - the Advanced Topographic Laser Altimetry System (ATLAS). The ICESat-2 Observatory, operating in a frozen 92 degree inclination orbit consisting of 1387 revolutions repeated every 91 days, is responsible for the collection and downlink of all science data. These data (as well as housekeeping telemetry data from both the Spacecraft and ATLAS) are stored on solid-state recorders. Data is downlinked to ground stations via an X-band communications link. The Observatory will also receive ground commands and transmit real-time housekeeping telemetry via an S-band link to the NASA Near Earth Network during nominal operations and to the Space Network immediately after launch and during contingency operations.

The Ground Segment provides for observatory command and control, monitoring, and health and safety of the Observatory on-orbit, as well as the generation of all data products from the level zero data transmitted from the observatory, and the distribution of these data products to the Data Center. The ground segment provides mission planning and scheduling, coordination with the ground stations for data downlink, and generation of the Observatory command loads necessary to execute the mission plan and protect the Observatory.

The Launch Support Segment (LSS) provides those assets and services associated with the launch vehicle (LV) and the mission integration planning necessary to place the ICESat-2 Observatory into the required orbit. Included along with the LV are all ground support equipment, property, and facilities

to integrate the ICESat-2 observatory with the LV, verify the launch service interfaces, and conduct pre-launch testing with the LV and ICESat-2 ground systems.

The ICESat-2 Observatory is designed to be accommodated by a Delta II launch vehicle. ICESat-2 will launch from the Western Range at the Vandenberg Air Force Base (VAFB) in the third quarter of 2017. Launch Support Segment activities are considered to be complete when the ICESat-2 successfully separates from the launch vehicle. The Launch Support Segment interfaces with both the Space Segment and the Ground Segment.

ATLAS Instrument

As noted above, ICESat-2

is a single instrument mission, consisting of the ATLAS laser altimeter. ATLAS collects three key pieces of information to measure the height of forest canopy, or changes in ice sheet elevation: the travel time from the altimeter to the target (such as the surface of the earth), the direction ATLAS was pointing when that travel time was measured, and the position of the observatory in space.

Unlike its single-beam predecessor from ICESat, ATLAS is a multi-beam, photon-counting laser altimeter. It illuminates 6 spots on the ground simultaneously by splitting the light from a single 1 nanosecond laser pulse. While the altimeter on ICESat operated at 40 Hz and used, producing a measurement every ~140m along-track, ATLAS will use lower-energy pulses at a repetition rate of 10 kHz to produce measurements every ~70 cm along track for each of the six spots. A small fraction of the transmitted laser light is scattered by the earth surface and atmosphere and collected by the ATLAS receiver, along with "background" light from sunlight also scattered by the earth and clouds. The ATLAS detectors record the arrival times of individual photons and can only distinguish signal photons from the laser and background photons after significant processing on the ground. Using precise measurements of both the time that a laser pulse is transmitted, and the times that photons are detected, we calculate the time of flight of a given photon to ~150 picoseconds.

In order to convert that time of flight measurement to an elevation, the ICESat-2 observatory carries a GPS antenna and receiver. The low-level data from the GPS is downlinked and processed on the ground to determine the position of the observatory, to within about 3 cm, at the time of each transmitted laser pulse. Once the observatory position is known, we can remove the effects of changes in the observatory altitude and convert differences in time of flight into elevation along the ground track illuminated by ATLAS.

The last key piece of information is the pointing direction. This is important, as it allows the ground segment to determine where on earth the laser spots illuminated for a given shot. In order to meet the mission requirement of knowing where the laser spots fell on the earth to within 6.5m, ATLAS has an advanced Laser Reference System (LRS). Within the LRS, ATLAS monitors the pointing of the laser beams and a star field with respect to a common reference structure and reports both to the ground.

Although these are the essential measurements that enable generation of the science data products, in order to product high quality measurements, ATLAS has a number of other capabilities. Perhaps the most important is ensuring the reflected light from the laser will be viewed by the ATLAS telescope and the time of the returning photons recorded. If the laser and telescope fall out of alignment, the ATLAS detectors will only record background photons. To avoid this situation, ATLAS uses an alignment monitoring control system to actively align the transmitted laser beams with the telescope field of view. This system monitors the pointing direction of the telescope, and uses a beam steering mirror to keep the laser spots in the telescope field of view.

Another important capability is the pointing control of the ICESat-2 observatory. Since one of the objectives of the mission is measure elevation change in the Polar Regions, it is imperative to illuminate the same ground tracks every 91 days. Therefore, the observatory needs to be able to control where the observatory is pointed and adjust as needed, as well as knowing where the observatory was actually pointed. To do this the spacecraft monitors where the laser beams are pointed with respect to the starfield, and uses reaction wheels to adjust the pointing direction of the observatory. The pointing control requirement for ICESat-2 is 45m.

ICESat-2 is NASA's next-generation laser altimeter, scheduled for launch in 2017, and will continue the important observations begun by ICESat. Together, these data sets will allow for continent wide estimates of changes in the Greenland, and Antarctic ice sheets over a 15-year period, long-term trends in sea-ice thickness, and enable determination of global vegetation height.

9241-7, Session 2

CYGNSS: NASA Earth Venture tropical cyclone mission

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The NASA Earth Venture Cyclone Global Navigation Satellite System (CYGNSS) is a spaceborne mission scheduled to launch in October 2016 that is focused on tropical cyclone (TC) inner core process studies. CYGNSS attempts to resolve one of the principle deficiencies with current TC intensity forecasts, which lies in inadequate observations and modeling of the inner core. CYGNSS is specifically designed to address these two limitations by combining the all-weather performance of GNSS bistatic ocean surface scatterometry with the sampling properties of a constellation of satellites. CYGNSS measurements of bistatic radar cross section of the ocean can be directly related to the near surface wind speed, in a manner roughly analogous to that of conventional ocean wind scatterometers. The technique has been demonstrated previously from space by the UK-DMC mission in 2005-6.

The CYGNSS constellation is comprised of 8 observatories in 500 km circular orbits at a common inclination angle of 35°. Each observatory contains a Delay Doppler Mapping Instrument (DDMI) which consists of a multi-channel GPS receiver, a low gain zenith antenna and two high gain nadir antennas. Each DDMI measures simultaneous specular scattered signals from the 4 GPS transmitters with the highest probable signal-to-noise ratio. This results in 32 wind measurements per second. An exploded view of one of the eight observatories is shown in Fig. 1.

CYGNSS spatial sampling is marked by 32 simultaneous single pixel "swaths" that are 25 km wide and, typically, 100s of km long. The temporal sampling is best described by a probability distribution of the revisit time at each location within the +/- 35o latitude coverage area. The median value of the revisit time is ~2 hours and the mean revisit time is ~6 hours.

The bistatic radar cross section of the ocean surface at the specular reflection point between a GPS transmitter and a CYGNSS receiver is measured in the form of Delay-Doppler Maps (DDMs). Wind speed is estimated from the DDMs using a minimum variance (MV) estimator. The MV estimator is a composite of wind estimates obtained from different observables that can be derived from the DDMs. Regression-based wind retrievals are developed for each observable using geophysical model functions that relate an observable to the surface wind speed.

The SPIE 2014 RS103 presentation will include an update on the status of the mission, including the latest mission schedule, the plans for science data products to be distributed to the ocean winds research community, the expected wind speed retrieval and temporal and spatial sampling performance, and the latest results of OSSE and on-orbit validation simulations.

9241-8, Session 2

Implementation of tropospheric emissions: monitoring of pollution (TEMPO)

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The updated status of TEMPO, as ot proceeds from formulation phase into implementation phase is presented. TEMPO, the first NASA Earth Venture Instrument, will measure atmospheric pollution for greater North America from space using ultraviolet and visible spectroscopy. TEMPO measures from Mexico City to the Canadian oil sands, and from the Atlantic to the Pacific, hourly and at high spatial resolution. TEMPO provides a tropospheric measurement suite that includes the key elements of tropospheric air pollution chemistry. Measurements are from geostationary (GEO) orbit, to capture the inherent high variability in the diurnal cycle of emissions and chemistry. The small product spatial footprint resolves pollution sources at sub-urban scale. Together, this temporal and spatial resolution improves emission inventories, monitors population exposure, and enables effective emission-control strategies.

TEMPO takes advantage of a GEO host spacecraft to provide a modest cost mission that measures the spectra required to retrieve O3, NO2, SO2, H2CO, C2H2O2, H2O, aerosols, cloud parameters, and UVB radiation. TEMPO thus measures the major elements, directly or by proxy, in the tropospheric O3 chemistry cycle. Multi-spectral observations provide sensitivity to O3 in the lowermost troposphere, reducing uncertainty in air quality predictions by 50%. TEMPO quantifies and tracks the evolution of aerosol loading. It provides near-real-time air quality products that will be made widely, publicly available.

TEMPO makes the first tropospheric trace gas measurements from GEO, by building on the heritage of five spectrometers flown in low-earth-orbit (LEO). These LEO instruments measure the needed spectra, although at coarse spatial and temporal resolutions, to the precisions required for TEMPO and use retrieval algorithms developed for them by TEMPO Science Team members and currently running in operational environments. This makes TEMPO an innovative use of a well-proven technique, able to produce a revolutionary data set.

TEMPO provides much of the atmospheric measurement capability recommended for GEO-CAPE in the 2007 National Research Council Decadal Survey, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. GEO-CAPE is not planned for implementation this decade. However, instruments from Europe (Sentinel 4) and Asia (GEMS) will form parts of a global GEO constellation for pollution monitoring later this decade, with a major focus on intercontinental pollution transport. TEMPO will launch at a prime time to be a component of this constellation

9241-9, Session 2

Surface Water and Ocean Topography (SWOT) mission formulation

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The Surface Water and Ocean Topography (SWOT) mission was recommended by the National Research Council's 2007 Earth Science Decadal Survey for implementation by NASA and in 2010 was designated by NASA's 2010 Climate Plan for launch by 2020. SWOT will enable new measurements for hydrology and oceanography through broad swath altimetry. The SWOT mission will provide measurements of water storage changes in terrestrial surface water bodies and will provide estimates of discharge in large (wider than 100m) rivers globally. SWOT will directly measure the surface water (lakes, reservoirs, rivers, and wetlands) component of the Earth's water cycle. The SWOT mission will also provide large-scale data sets of sea surface height (resolving scales of 15km and larger) allowing the characterization of ocean mesoscale and submesoscale circulation. SWOT's primary science instrument is a Ka band Radar Interferometer (KaRIn). The SWOT payload also includes a Jason-class radiometer for tropospheric path delay correction; a Jason-class Nadir Altimeter; and a precision orbit determination system consisting of a GPS Payload, a DORIS receiver, and a Laser Retro-reflector Assembly (LRA). The SWOT mission is an international partnership between NASA and the French Centre National d'Etudes Spatiales (CNES) with contributions from the Canadian Space Agency (CSA) and the United Kingdom Space Agency (UKSA). SWOT is currently in Formulation (Phase B) and has a planned launch date in October 2020.

9241-10, Session 2

Mission design for NISAR repeat-pass Interferometric SAR

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The NASA-ISRO SAR (NI-SAR) mission utilizes repeat-pass interferometric SAR (RP-InSAR) techniques to obtain surface change data required for science investigations. The quality and accuracy of change data, as derived from InSAR, depend on how well the orbit (positions) and attitude (pointing) of the observatory can be repeated for the target area to be observed repeatedly throughout the science observation life of the mission. This paper describes NI-SAR requirements for repeat orbit and attitude in order to meet science requirements, preliminary error budget allocations, and implementation approach. The NI-SAR mission is a partnership between NASA and the Indian Space Research Organisation (ISRO).

9241-11, Session 3

Overview of ESA Earth observation missions *(Invited Paper)*

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No Abstract Available

9241-12, Session 3

Meteosat third generation imager: simulation of the flexible combined imager instrument chain

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The Meteosat Third Generation (MTG) Programme is the next generation of European geostationary meteorological systems. The first MTG satellite, MTG-I1, which is scheduled for launch at the end of 2018, will host two imaging instruments: the Flexible Combined Imager (FCI) and the Lightning Imager. The FCI will continue the operation of the SEVIRI imager on the current Meteosat Second Generation satellites (MSG), but with an improved spatial, temporal and spectral resolution, similar to GOES-R (of NASA/NOAA).

Unlike SEVIRI on the spinning MSG spacecrafts, the FCI will be

mounted on a 3-axis stabilised platform and a 2-axis tapered scan will provide a full coverage of the Earth in 10 minute repeat cycles. In order to assess some of the data acquisition and processing aspects which will apply to the FCI, a simplified end-to-end imaging chain prototype was set up. The simulation prototype consists of four different functional blocks:

- A function for the generation of FCI-like references images

- An image acquisition function for the FCI Line-of-Sight calculation and swath generation

- A processing function that reverses the swath generation process by rectifying the swath data

- An evaluation function for assessing the quality of the processed data with respect to the reference images

This paper presents an overview of the FCI instrument chain prototype, covering instrument characteristics, image acquisition, and processing aspects. In particular, it provides in detail the description of the generation of references images, highlighting innovative features, but also limitations. This is followed by a description of the image acquisition process, and the rectification and evaluation function. The latter two are described in more detail in a separate paper.

Finally, results from the prototype imaging chain are shown, including generated datasets, evaluation of results and conclusions derived from the first tests. An outline of planned extensions to the prototype and its role in the MTG Ground Segment development conclude the presentation.

9241-13, Session 3

The EarthCARE satellite payload

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EarthCARE is ESA's third Earth Explorer Core Mission, implemented in collaboration with JAXA, which provides one payload instrument. The satellite's two passive and two active instruments will allow unique data product synergies, which are intended to improve our understanding of atmospheric cloud–aerosol interactions and of the Earth's radiative balance. The micro-scale role of clouds and aerosols in reflecting incident solar radiation and trapping Earth emitted infrared radiation will be explored, towards enhancing climate and numerical weather prediction models. Global, collocated measurements, characterising cloud and aerosol structure and physical properties, will be collected. The 3-axis stabilised, two tonne satellite will use a 393 km sun-synchronous orbit, with a descending node at 14:00 and repeat cycle of 25 days. The three year nominal lifetime includes six months commissioning. This paper will give a description of the payload, consisting of two active instruments: an ATmospheric LIDar (ATLID) and a Cloud Profiling Radar (CPR), and two passive instruments: a Multi Spectral Imager (MSI) and a BroadBand Radiometer (BBR).

ATLID operates in the UV, at 355 nm, and provides atmospheric echoes with a vertical resolution of 100 m up to an altitude of 40 km. The UV wavelength provides a less divergent beam with smaller footprint than visible wavelengths, consequently reducing the receiver telescope's field of view requirement and thereby reducing unwanted, scattered sunlight contributions in the scene. Using very high spectral resolution filtering in the receiver the relative contributions of Mie (attributed to aerosols) and Rayleigh (attributed to molecular) back scattering will be resolved, allowing aerosol optical depth to be deduced. Mie co- and cross-polarised components are also measured, making possible deductions regarding the physical characteristics of the aerosol particles.

JAXA's 94.05 GHz Cloud Profiling Radar operates with a pulse width of 3.3 ?m and repetition frequency 6100 to 7500 Hz. The highly sensitive, millimetre wave, 2.5 m aperture, cloud radar will retrieve data on high altitude ice clouds, particularly in the troposphere. Its capability to measure Doppler shift in the backscatter signal will allow measurement of the vertical motion of particles to an accuracy of about 1 m/s. The data will be studied to deduce vertical updrafts within clouds and particle sedimentation rates.

The MSI will provide retrievals of cloud and aerosol as well as imagery to give context to the active instrument measurements in order to construct 3-D scenes of clouds and aerosols. The four solar channels (visible, near-IR and shortwave-IR) and three thermal infrared channels cover 35 km on one side to 115 km on the other side of ATLID and CPR observations, with a pixel size of 500 m.

The BBR measures reflected solar radiation and emitted thermal radiation from the scene. To reduce uncertainty in the radiance to flux conversion from spatially inhomogeneous scenes, three independent views are observed for each scene: forward looking, at nadir and aft looking. The combined data allows more accurate flux calculation and additional improvements can be realised during ground processing using data from the MSI. BBR measures in two channels, Total Wave from 0.25 to 50 ?m and Short Wave from 0.25 to 4.0 ?m.

9241-14, Session 3

The TROPOMI instrument is in final integration and heads for a bright future

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The TROPOspheric Monitoring Instrument (TROPOMI) is a UVNS imaging spectrometer that uses backscattered solar radiation for air-quality determination and climate research. TROPOMI is the single payload on the Sentinel-5 Precursor platform, part of the ESA/EU Copernicus programme.

As compared to its predecessors SCIAMACHY (2002) and OMI (2004), TROPOMI further improves the ground resolution to 7 x 7 km2 and improves its signal-to-noise performance to have it fit for dark scenes (2 – 5 % albedo) instead of the earlier average of 30 %.

TROPOMI is now almost fully integrated and shows an excellent performance, for all the parameters we know at present. The paper describes this instrument performance and the most important challenges that had to be overcome to obtain this.

The paper will also describe the upcoming calibration campaign, which was optimised in duration to the maximum extent possible.

TROPOMI is expected to provide outstanding data to its users after launch in early 2016.

9241-15, Session 4

The Copernicus Sentinel-5 mission for operational atmospheric monitoring: status and developments

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Sentinel-5 is an atmospheric monitoring mission planned in the frame of the Copernicus programme, previously known as

GMES (Global Monitoring for Environment and Security). The Copernicus initiative is headed by the European Commission (EC) in partnership with the European Space Agency (ESA).

The objective of the Sentinel-5 mission, planned to be launched in 2021, is the operational monitoring of trace gas concentrations for atmospheric chemistry and climate applications. It will provide accurate measurements of key atmospheric constituents such as ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, methane, formaldehyde and aerosol properties. The space segment will be implemented as an imaging spectrometer to be flown on EUMETSAT's Metop Second Generation satellites.

Although there is a considerable heritage from past and present scientific missions like GOME, SCIAMACHY, GOME-2 and OMI, the demanding requirements of the operational Sentinel-5 mission call for a significant increase of spatial and spectral coverage, revisit frequency, spatial resolution, and radiometric accuracy. From a sun-synchronous LEO orbit Sentinel-5 measurements will provide a daily global coverage at an unprecedented spatial resolution of 7x7 km at nadir. The pushbroom imaging grating spectrometer will acquire continuous spectra of Earthshine radiance covering the UV (270-370 nm), Vis (370-500 nm), NIR (685-775 nm) and SWIR (1590-1675 nm; 2305-2385 nm) spectral regions. The spectral resolution varies from 1 nm in the UV1 (270-300 nm), used for retrieval of stratospheric O3 profiles, over 0.5-0.4 nm for the visible and NIR range, respectively, to 0.25 nm in the two SWIR bands. A spectral resolution element is sampled 2.5-3.0 detector pixels in order to avoid spectral aliasing.

While SNR limits are in principle always achievable by increasing the pupil size (and with it size and mass) of the instrument, the demanding requirements for relative and absolute radiometric accuracy are pushing technology to the limits of feasibility. The relative spectral radiometric accuracy describes spurious features in the measured spectra, which propagate into the retrieval error. There are many contributors to this error, including speckles from the Sun calibration diffuser, spectral straylight and polarization scrambler effects. The Sentinel-5 requirements limit the polarization sensitivity of the instrument to below 0.5% in the UV, Vis and NIR, which is only achievable by utilizing a spatial pseudo-depolarizer as an optical component, which depolarizes the light collected by the telescope. Another contributor to spectral errors are radiometric artefacts arising from the spatially heterogeneous nature of the radiance emanating from the Earth surface (due to irregular cloud cover or albedo variations within a spatial sample). The varying radiance levels across the slit result in an inhomogeneous illumination of the entrance slit, and consequently in a distortion of the Instrument Spectral Response Function. Slit homogenizers are proposed in order to mitigate radiometric errors arising from naturally occurring scene heterogeneity.

The paper reports on the outcome of the technical feasibility studies carried out by industrial consortia, supported by the European Space Agency (ESA). The driving requirements, technological challenges and proposed solutions will be discussed as well as several technology pre-developments that have been completed aiming at mitigating development risks.

9241-16, Session 4

Sentinel-2 multispectral instrument pre-flight characterisation results and calibration/validation approach for the in-orbit commissioning phase

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The Copernicus programme is a joint initiative of the European Commission (EC) and the European Space Agency (ESA), designed to establish a European capacity for the provision and use of operational monitoring information for environment and security applications. ESA's role in Copernicus is to provide the definition and the development of the space- and ground-related system elements. The key mission objectives for Sentinel-2 are: (1) To provide systematic global acquisitions of high-resolution multi-spectral imagery with a high revisit frequency, (2) to provide enhanced continuity of multi-spectral imagery provided by the SPOT series of satellites, and (3) to provide observations for the next generation of operational products such as land-cover maps, land change detection maps, and geophysical variables. The corresponding user requirements have driven the design towards a multi-spectral Earth-observation system with 13 spectral bands spanning from the visible and the near infrared to the short wave infrared. The spatial resolution varies from 10 m to 60 m depending on the spectral band with a 290 km field of view. This unique combination of high spatial resolution, wide field of view and large spectral coverage will represent a major step forward compared to current multi-spectral missions. During full operations two identical satellites will be maintained in the same orbit with a phase delay of 180° providing a revisit time of five days at the equator). The launch readiness of first Sentinel-2 satellite is planned in the second quarter of 2015.

The presentation will provide an overview of the current development status with focus on instrument performances based on pre-flight characterization results. The approach for the MSI Cal/Val activities for the in-orbit commissioning phase will be also presented with a focus on the activities and tools that have been developed.

9241-17, Session 4

TROPOLITE, on the path of atmospheric chemistry made simple

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Accurate, reliable and stable long term measurements of Earth's Atmospheric Chemistry from Space are currently done by complex instruments, whose mass is in excess of 100 Kg. TROPOMI is the more recent instrument being developed jointly by ESA and NSO and due for launch in 2015. TROPOMI, consisting of four spectrometers ranging from UV to SWIR, is paving the way to the development of high performance spectrometers that will compose the backbone of the European Copernicus system.

The objective of TROPOMI is to measure trace gases with an accuracy one order of magnitude better of what is currently done from Space. While teams of engineers are still busy finalizing TROPOMI and at the same time are retrofitting the design for the next generation, ESA and NSO have launched an initiative along a different development axis: to explore the possibility of a lighter version of TROPOMI, to address a market valuing a cost effective solution and willing to accept an instrument yet very performing, but with limited functionalities.

TROPOLITE, as it is dubbed, leverages on all the technology developments and the lessons learnt from TROPOMI, but with the clear objective of a design to cost solution and with mass and power within the envelope of a payload of a small satellite, namely 20kg and 30W. The objective of TROPOLITE is to address a larger user base that is interested in an affordable instrument to perform some specific tasks relevant to Air Quality and/or Climate. The whole TROPOLITE concept is based on a turn key solution, where the user learning curve to operate the instrument and to retrieve the data is kept to a minimum.

The paper, after a short overview of the TROPOMI design and current status, presents the design philosophy of TROPOLITE, and shows what are the technologies and processes stemming from the experience gained with TROPOMI that make possible a simplified, but still very performing, version of TROPOMI. A comparison in terms of performance and functionalities of the two instruments is discussed. Finally, the development plan from the current development status of TROPOLITE up to Qualification Model is presented.

9241-18, Session 4

Study of a passive companion microsatellite to the SAOCOM-1B satellite of Argentina, for bistatic and interferometric SAR applications

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The concept of a passive receiving mini-satellite flying in formation with an active satellite for bistatic SAR imaging and single-pass interferometry has been the subject of many studies (e.g., the Surrey BRISAT, the Italian BISSAT, the CNES Interferometric Cartwheel, the NASA/JPL TOPSAT, the ESA Sentinel-1 CompSAR).

SAOCOM is an L-band, full-polarimetric SAR system to be deployed by Argentina in 2015 (SAOCOM-1A) and 2017 (SAOCOM-1B). The two satellites shall be part of the SIASGE disaster management constellation that also includes the X-band Cosmo-Skymed satellites. The main driver of the SAOCOM mission is the determination of soil moisture over an area that includes the Pampas region and the catchments from the fraction of the del Plata Basin (≈ 83000000 ha), which is the main Argentinean region dedicated to agriculture and cattle production, hence its major socio-economic value.

We report the results of a preparatory study aimed at exploring candidate applications that could benefit from a passive micro-satellite accompanying SAOCOM-1B, and to carry out a limited demonstration, based on data acquired during ESA airborne campaigns, of selected applications.

In a first step of the study, the potential applications were identified and prioritized based on the mission context and strategic applications, scientific need, and feasibility.

The first category of applications involves formation-flying of the two satellites with typical baselines of 10 to 20 km across-track and 1 km along-track (depending on the Master imaging beams characteristics), and includes: 3D vegetation structure by SAR tomography and PolInSAR, agriculture monitoring using time series of InSAR coherence maps, InSAR topographic mapping, ocean current and sea ice motion using along-track InSAR.

The second category corresponds to long bistatic baseline configurations (from 200 to 600 km depending on beam) and includes: multi-angle and multi-polarisation bistatic radar cross section measurements of man-made and natural targets for improved detection, segmentation and classification over urban rural areas, surface roughness and dielectric constant retrieval, topographic mapping by SAR radargrammetry, and bistatic SAR processing developments.

The next step of the study was to carry out some demonstrations using data sets acquired during the BioSAR 2007-2009, TropiSAR 2009 and IceSAR 2007 campaigns. A P-band InSAR digital elevation model was generated from BioSAR 2007 data. Time-series of interferometric coherence maps were obtained as a tool for change detection and monitoring. PolInSAR processing was carried out on BioSAR 2007 and IceSAR data.

Based on the outputs of this activity and on the results of a study carried out at the ESA Concurrent Design Facility, a Phase A study is to be started in the 2014 timeframe.

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9241-19, Session 4

ALTIUS: a spaceborne AOTF-based UV-VIS-NIR hyperspectral imager for atmospheric remote sensing

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Since the recent losses of several atmospheric instruments with good vertical sampling capabilities (SCIAMACHY, SAGE II, SAGE III, GOMOS, OSIRIS, ...), the scientific community is left with very few sounders delivering concentration profiles of key atmospheric species for the radiative balance of the Earth. The situation is so critical that at the horizon 2020, less than five such instruments will be on duty (most probably only 2 or 3), whereas their number topped at more than 15 in the years 2000. In parallel, recent inter-comparison exercises among the climate chemistry models (CCM) have shown large differences in vertical distribution of constituents (see SPARC CCMVal report f.i.), stressing the need for more vertically-resolved data at all latitudes.

In this frame, the Belgian Institute for Space Aeronomy (IASB-BIRA) proposed a gap-filler small mission called ALTIUS (Atmospheric Limb Tracker for the Investigation of the Upcoming Stratosphere), which is currently in preliminary design phase (phase B according to ESA standards).

Taking advantage of the good performances of the PROBA platform (PROBA-1, PROBA-2, PROBA-V) in terms of pointing precision and accuracy, on-board processing ressources, and agility, the ALTIUS concept relies on a hyperspectral imager observing limb scattered radiance and solar/stellar occultations every orbit. The objective is twofold: the imaging feature allows to better assess the tangent height of the sounded air masses (through easier star tracker information validation by scene details recognition), while its spectral capabilities will be good enough to exploit the characteristic signatures of many molecular absorption cross-sections (O3, NO2, CH4, H2O, BrO,...). The payload will be divided in three independent optical channels, associated to separated spectral ranges (UV: 250-450nm, VIS: 450-800nm, NIR: 900-1800nm). This approach also offers better risk mitigation in case of failure in one channel.

In each channel, the spectral filter will be an acousto-optical tunable filter (AOTF). Such devices offer reasonable étendue with good spectral resolution and excellent robustness and compactness. Their use is widespread in many spectral imaging applications (fluorescence detection, pattern identification, product quality assessment, etc ...). TeO2-based AOTF's have also been used in space missions towards Mars and Venus (MEX and VEX, ESA). While such TeO2 crystals are common in VIS-NIR applications, they are not transparent below 350nm. Recent progress towards UV AOTF's have been made with the advent of KDP-based filters. Through collaboration with the Moscow State University (MSU), several experiments were conducted on a KDP AOTF and gave confidence on this material.

Here, we present the general concept of ALTIUS and its optical design with particular attention on the AOTF. Several results obtained with optical breadboards for the UV and VIS ranges will be exposed, such as the O3 and NO2 absorption cross-section measurements, or spectral images. These results illustrate the spectral and optical performances to be expected from an AOTF-based hyperspectral imager. Their implications for ALTIUS will be discussed.

9241-20, Session 5

Overview of Japanese Earth observation programs *(Invited Paper)*

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Six programs, i.e. TRMM, ADEOS2, ASTER, GOSAT, GCOM-W1, and GPM are going on in Japanese Earth Observation programs. PR on TRMM and ASTER on EOS-Terra are operating well except SWI channels of ASTER. ASTER SWI channels have

stopped the operation because of a refrigerator failure in 2009. ADEOS2 was failed, but AMSR-E on Aqua was operating until 14, Oct. 2011. AMSR-E has stopped at that time because of the antenna driving mechanism's torque increase. Now, AMSR-E instrument has been on from March 2012 without antenna rotation and antenna rotation has been started from Dec. 2012 with 2rpm. GCOM-W1 was launched on May, 2012.GCOM-W1 carries AMSR2. The orbit is A-train and has higher resolution than AMSR-E. GOSAT was launched on 23, Jan., 2009. GOSAT carries 2 instruments, i.e. a greenhouse gas sensor (TANSO-FTS) and a cloud/aerosol imager (TANSO-CAI). TANSO-FTS is a Fourier transform spectrometer (FTS) and covers 0.76 to 15 ?m region with 0.2 cm-1 resolution. TANSO-CAI is a 5 channel push broom scanner to observe aerosols and clouds. Both sensors are operating well. SMILES was on JEM of ISS. SMILES is a sub-millimeter limb sounding instrument using super conducting mixer and measures stratospheric ozone and related compounds. Unfortunately, SMILES stopped its operation on 21, April, 2010. ALOS was launched on 24, Jan., 2006 and stopped on 22, April, 2011 by power anomaly. ALOS carried three instruments, i.e., PRISM, AVNIR-2 and PALSAR. PRISM is a 3 line panchromatic push broom scanner with 2.5m IFOV. AVNIR-2 is a 4 channel multi spectral scanner with 10m IFOV. PALSAR is a full polarimetric active phased array SAR. GPM core satellite is a joint project with NASA and carries two instruments. JAXA has developed DPR. DPR has Ka band channel in addition to Ku band channel. NASA has developed GMI which is a microwave imager. GPM core satellite was launched on February 2014 and operating well. Next generation satellites will be launched in 2014-2017 timeframe. They are ALOS2, GCOM-C1, EarthCare, GOSAT2 and ALOS3. ALOS F/O is composed of 2 satellites like GCOM. One is called ALOS-2 and will carry L-band SAR while the other is called ALOS-3 and will carry optical sensors. ALOS-2 will be launched on May, 2014. GCOM-C1 will carry SGLI. SGLI has polarization channels. GCOM-C will be launched on 2016. Another project is EarthCare. It is a joint project with ESA and JAXA is going to provide CPR with NICT. EarthCare will be launched on 2016. GOSAT2 is a follow on of GOSAT and will carry 2 instruments, i.e. TANSO-FTS2 and TANSO-CAI2. FTS2 is an improved version of FTS on GOSAT, but CAI2 is a 10 channel ultra violet to near infrared imager.

9241-21, Session 5

ASTER TIR onboard calibration over fourteen years

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The ASTER Instrument is one of the five sensors on the NASA's Terra satellite on orbit since December 1999. ASTER consists of three radiometers, VNIR, SWIR and TIR whose spatial resolutions are 15 m, 30 m and 90 m, respectively. Unfortunately SWIR stopped taking images since May 2008 due to the offset rise caused by the detecor temperature rise, but VNIR and TIR are taking Earth images of good quality. The TIR radiometer has five bands from 8 to 12 ?m in the thermal infrared region. Each band has ten detectors. The detectors are cooled at 80 K precisely by using a Stirling cooler within 0.1 K. TIR is radiometrically calibrated by a single onboard blackbody. In the normal operation mode the blackbody is kept at 270 K, and the offset term C0 in a quadratic radiometric calibration equation is adjusted at that temperature before each Earth observation. Once in 49 days the gain term C1 can be updated by a long term calibration in which the heated blackbody is measured at 270, 300, 320, and 340 K. The nonlinear term C2 is kept constant since the first on-orbit data. We use approximation equations for the coefficients C0 and C1 to predict the most reasonable radiometric calibration coefficients (RCC) at the time of the observation. These coefficients are updated once a year or in two years. The degradation at band 12 is largest and 42% and that at band 10 is smallest and 18%. There are some discussions of the causes of the responsivity degradation of TIR from the spectral feature of the degradation. One of the possible causes is contamination accretion by outgas of silicone SE9188 RTV used for TIR perhaps followed by the ultraviolet radiation. The absorption spectra of outgas of this silicon was measured at JAXA and the absorption spectra showed similar to the TIR degradation in the early days on orbit. The ASTER science team is proposing second lunar calibration at the end of terra mission for the degradation estimation of VNIR independent of onboard and vicarious calibration. ASTER experienced first lunar calibration in April 2003. At that time many of the TIR bands were saturated. Due to the responsivity degradation, the dynamic range of the TIR instrument has expanded to higher temperature. At least four bands of TIR will not saturate in the next lunar calibration. Therefore we can estimate the optical characteristics of the TIR more quantitatively.

9241-22, Session 5

Current status of the Global Change Observation Mission 1st-Water SHIZUKU (GCOM-W1) and the Advanced Microwave Scanning Radiometer 2 (AMSR2)

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Japan Aerospace Exploration Agency (JAXA) launched the Global Change Observation Mission 1st - Water (GCOM-W1) or "SHIZUKU" (meaning "droplet" in Japanese) in 18 May 2012 (JST) from JAXA's Tanegashima Space Center. GCOM-W1 is not a name of single satellite mission. It is a part of global and long-term observation program with two complementary medium-sized satellites (GCOM-W and GCOM-C series) and three generations (10-15 years) for stable data records. The GCOM-W1 satellite is the first generation of GCOM-W series. The GCOM-W1 satellite joins to NASA's A-train orbit since June 2012, and its observation is ongoing. The GCOM-W1 satellite carries the Advanced Microwave Scanning Radiometer 2 (AMSR2). AMSR2 is multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands, and successor microwave radiometer to the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) loaded on the NASA's Aqua satellite launched in May 2002. AMSR-E halted its scientific observation on October 2011 because torque to maintain the rotation speed in regular observations (40 rotations per minute) reached the design limit. However, AMSR-E restarted observation in the slower rotation speed (2 rotations per minute) in December 2012. Currently, cross-calibration between AMSR-E and AMSR2 is underway.

AMSR2 is designed almost similarly as AMSR-E, and has a conical scanning system with large-size offset parabolic antenna, a feed horn cluster to realize multi-frequency observation, and an external calibration system with two temperature standards. However, some important improvements are made. For example, AMSR2's main reflector is expanded from 1.6 m of AMSR-E to 2.0 m to observe the Earth's surface in higher spatial resolution, and 7.3-GHz channel is newly added to detect radio frequency interferences at 6.9 GHz.

JAXA started distribution of AMSR2 brightness temperature products to public since January 2013 after initial calibration/validation period through the GCOM-W1 Data Providing Service (https://gcom-w1.jaxa.jp/). After that, algorithms to retrieve 8 standard geophysical values (water vapor, cloud liquid water, precipitation, sea surface temperature, sea surface wind speed, sea ice concentration, snow depth, and soil moisture) were modified, and distribution of the (standard) products of these standard geophysical values (standard products) to public was also started since May 2013.

After starting distribution of AMSR2 products, JAXA keeps validation of these products in order to improve their accuracy, and development of retrieval algorithms for more challenging

geophysical values (research algorithms) in cooperation with other researchers and projects. In this paper, we present the current operation status of AMSR2.

9241-23, Session 5

Validation activity for GCOM-C1/SGLI land standard products

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Japan Aerospace Exploration Agency (JAXA) is going to launch new Earth observation satellite GCOM-C1. The core sensor of GCOM-C1, Second Generation Global Imager (SGLI) has a set of along track slant viewing Visible and Near Infrared Radiometer (VNR). These multi-angular views aim to detect the structural information from vegetation canopy, especially forest canopy, for estimating productivity of the vegetation. SGLI Land science team has been developing the algorithm for above ground biomass, canopy roughness index, etc.

In this paper, we introduce the ground observation method developed by using Unmanned Aerial Vehicle (UAV) , Ground LIDER system can be applied for various types of forest in order to contribute the algorithm development and its validation.

9241-24, Session 5

GOSAT on-orbit status over 5-year nominal operation

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The Greenhouse Gases Observing Satellite (GOSAT) is a Japanese mission to monitor greenhouse gases such as CO2 and CH4 from space. The GOSAT was launched on 23 January 2009. On-board science instruments consist of the Fourier Transform Spectrometer (TANSO-FTS) and the Cloud and Aerosol Imager (TANSO-CAI). The FTS covers wide wavelength range from SWIR to TIR by simultaneous observations with high spectral resolution of 0.2 cm-1. The FTS has 3 polarized SWIR bands, which are 0.76, 1.6 and 2.0 microns of O2, CO2, and CH4 absorptions. The TIR band observes from 5.5 to 14.3 microns, which includes CO2, CH4, O3 and H2O absorptions. The FTS observes globally with grid points of 10 km IFOV by separate pointing. The CAI is carried 4 radiometers of 0.38, 0.67, 0.87, and 1.60 microns to detect cloud and aerosol interference in the FTS IFOV with high spatial resolution and wide swath of 1000 km.

The GOSAT acquires greenhouse gases observation data over 5 years in nominal operation phase and extends the operation. The calibration accuracies are evaluated in annual trends. The radiometric accuracies of the SWIR bands are monitored by the solar diffuser, lunar calibration and stable calibration sites (Railroad valley and Sahara desert) by comparison of other coincident satellite data and simulated radiance using in-situ field experiment data. The TIR radiances are optimized by the polarized calibration using polarization reflectance and transmittance of the optical components and emissivity of the on-board blackbody. The radiometric accuracy of the TIR band is evaluated by comparison of other coincident satellite sensor such as AIRS. The geometric accuracies are monitored the GCPs on reference image and coastline database continuously. The Level 1 product is currently processed by the latest v161.160 and will be updated to v200 series soon. This presentation shows the on-orbit status of TANSO FTS and CAI over 5-year nominal operation.

9241-25, Session 6

The current status of GOSAT-2: mission and sensor system

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Greenhouse gases Observing SATellite (GOSAT) was launched on January 23, 2009, to monitor the global column concentration of carbon dioxide (CO2) and methane (CH4) from space. Over five years operational periods, the useful scientific data sets and interesting articles for carbon source/sink evaluation were produced and published, and on 23rd of January of this year the nominal operation period completed and moved to addional operation phase.

GOSAT has accomplished the accuracy targets which is highest ever for any observations from space with involvement of the information of the boundary layer.

And currently, the importance of space-based carbon observation has been approved and desired the continuous observation in toward. Through the GOSAT operation, we learned a lot of things on the instrument, software, processing algorithm and operation; what should be improved in the following mission. To elucidate the carbon cycle more precisely, our experiences regarding observation performances as well as hardware design were reflected on the mission requirements on GOSAT-2.

The requirements on GOSAT-2 observation are improvements of the observation performance such as signal to noise ratio and the number of the useful data.

In addition, it has been required to observe the correlated matter which is useful to detect the anthropogenic emission of greenhouse gases.

The principal requirements are measuring the CO2 concentration with the accuracy of 0.5 ppm at 500km and 2,000km mesh spatial resolution over the land and ocean, respectively and 1 month average, estimating the net flux with the error of 100% and measuring the Carbon Monoxide as the correlated matter of the anthropogenic emission of the greenhouse gases to study the detection of that.

Based on the feasibility studies including sampling strategy, band expansion, mapping capability, the hardware system requirements were defined.

To improve the measurement accuracy, the signal to noise ration will be increased by the extention of the aperture size and cooling the after optics as well as the thermal detectors. And to increase the number of the useful data, GOSAT-2 will equip the function to avoid the clouds during the observation using the images obtained by the monitor camera in FTS.

To observe the carbon monoxide, the 2.3?m observation channel will be added. This function will be realized by the extention of the 2.0?m observation band to 2.3?m.

The pointing angle in the along track direction will be extend from 20 degrees of GOSAT to 40 degrees to expand the observation area over the ocean where the sun glint is observed. This will make it possible to increase the number of the observation points over the ocean and contribute to the global observation including the ocean.

The cloud and aerosol imager data on GOSAT have been used to compensate the FTS data for the aerosol and to detect clouds. And the cloud and aerosol imager for GOSAT-2 will observe the additional observation channels to reinforce the aerosol observation abilities.

In this presentation, the design og the mission instruments and satellite system and the specification and development schedule will be shown.

9241-26, Session 6

Orbital checkout result of the dual-frequency precipitation radar on the global precipitation measurement core spacecraft

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The Dual-frequency Precipitation Radar (DPR) on the Global Precipitation Measurement (GPM) core satellite was developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). The GPM is a follow-on mission of the Tropical Rainfall Measuring Mission (TRMM). The objectives of the GPM mission are to observe global precipitation more frequently and accurately than TRMM. The frequent precipitation measurement about every three hours will be achieved by some constellation satellites with microwave radiometers (MWRs) or microwave sounders (MWSs), which will be developed by various countries. The accurate measurement of precipitation in mid-high latitudes will be achieved by the DPR. The GPM core satellite is a joint product of National Aeronautics and Space Administration (NASA), JAXA and NICT. NASA developed the satellite bus and the GPM microwave radiometer (GMI), and JAXA and NICT developed the DPR. JAXA and NICT developed the DPR through procurement. The contract for DPR was awarded to NEC TOSHIBA Space Systems, Ltd.

The configuration of precipitation measurement using an active radar and a passive radiometer is similar to TRMM. The major difference is that DPR is used in GPM instead of the precipitation radar (PR) in TRMM. The inclination of the core satellite is 65 degrees, and the flight altitude is about 407 km. The non-sun-synchronous circular orbit is necessary for measuring the diurnal change of rainfall similarly to TRMM. The DPR consists of two radars, which are Ku-band (13.6 GHz) precipitation radar (KuPR) and Ka-band (35.5 GHz) precipitation radar (KaPR). The objectives of the DPR are

(1) to provide three-dimensional precipitation structure including snowfall over both ocean and land,

(2) to improve the sensitivity and accuracy of precipitation measurement,

(3) to calibrate the estimated precipitation amount by MWRs and MWSs on the constellation satellites.

The DPR consists of Ku-band (13.6 GHz) precipitation radar (KuPR) and Ka-band (35.5 GHz) precipitation radar (KaPR). The KuPR unit will measure 2.6m X 2.4m X 0.7m in size. The KaPR unit will measure 1.3m X 1.5m X 0.8m in size. Both KuPR and KaPR have almost the same design as TRMM PR. The DPR system design and performance were verified through the development test and the proto flight test. DPR has handed over to NASA and integration of the DPR to the GPM core spacecraft have completed in May 2012. GPM core spacecraft satellite system test has completed in November 2013. The result of the satellite system test concerning to the DPR satisfied system requirements.

GPM core observatory was shipped to Tanegashima Space Center, JAPAN and Launch Site Operations has started on November 2013 and GPM core observatory was launched at 18:37:00 (UT) on February 27, 2014 successfully. DPR orbital check out started in March 2014 and it will be completed in April 2014. The orbital check out result of DPR will be reported.

9241-27, Session 6

ALOS-2 launch and early orbit operation result

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The Advanced Land Observing Satellite-2 (ALOS-2) is a follow-on mission of ALOS and its major objectives are disaster monitoring and comprehensive land monitoring (land and infrastructure, agriculture and global rain forests) by using Phased Array type L-band Synthetic Aperture Radar-2 (PALSAR-2). Key mission characteristics are high-resolution (1 to 10m) with wide swath (25 - 70km), long lifetime of 5 years (7 years target), short recurrent cycle in 14 days and high duty SAR acquisition up to 50 % of orbital period. PALSAR-2 will have enhanced performance in both high resolution and wide swath compared to PALSAR. It will allow comprehensive monitoring of disasters. Wider bandwidth and shorter revisit time will give better conference for INSAR data analysis such as crustal deformation and deforestation.

To meet the requirement of high-resolution and wide-swath observation, high-speed and large-capacity mission data handling is necessary. PALSAR-2 will generate huge amounts of data because of the enhanced performance and higher image resolution. The maximum data rate of PALSAR-2 after the data compression is 800 Mbps, which varies with the observation mode, and an effective downlink to the ground station is necessary. ALOS-2 has an improved data handling function which consists of a high-rate and huge-amount storage system, Mission Data Handling System (MDHS), and two types of high-rate transmission systems, Direct Transmission (DT) and Data Relay an Communication (DRC).

To improve the coherency of the repeat-pass SAR interferometry observation, precise maintenance of the satellite osculating orbit with respect to the reference trajectory in the Earth-fixed frame is necessary. However, as a consequence, it requires frequent orbit maneuvers. The JAXA Guidance and Control Group (GCG) has been studying an autonomous orbit maintenance algorithm for both in-plane orbit control and out-of-plane orbit control on Earth observation satellites. Exploiting the research mentioned above, an onboard software algorithm for ALOS-2 was developed.

During system Proto-Flight Model test, electrical design was confirmed, such as high data rate interface between PALSAR-2 and mission data handling system. The integration of system PFM started in October, 2011, and System Proto Flight Test (PFT) has started January, 2012. Then total performances of satellite system were confirmed as the all subsystems and all components were operated along with the estimated operational scenario in orbit. Especially, regarding to the observation mode of PALSAR-2 and the transmission data rate of DT and DRC, every available combinations was tested and confirmed to work as expected. These tests were conducted continuously for more than 3 days, which represents 41 orbit cycles. From the above verifications, the requirements of total function and performance of system was confirmed to satisfy the requirement. The PFM of ALOS-2 is under the final check and preparation for tha launch at JAXA's Tanagashima Space Center. This paper describes the ALOS-2 satellite system design. The initial operation results and its performance evaluation are also described.

9241-28, Session 6

Recent status of the JAXA/EarthCARE algorithm development

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The objective of the EarthCARE mission is to evaluate the radiative interaction and radiative forcing of cloud and aerosol, and to reduce the uncertainties in global warming prediction by measuring the three dimensional global structure of clouds

and aerosols, the most uncertain parameter in the numerical climate. There are four payloads on the EarthCARE satellite; a Cloud Profiling Radar (CPR), an ATmospheric LIDar (ATLID), a Multi-Spectral Imager (MSI) and a Broadband Radiometer (BBR). The CPR, developed jointly by Japan Aerospace Exploration Agency and National Institute of Information and Communications Technology, is the world's first satellite-borne Doppler cloud radar. The other three sensors are developed by European Space Agency. ATLID is a High Spectral Resolution Lidar which has the capability to independently observe the Rayleigh and Mie scattering signal to retrieve the vertical profiles of cloud and aerosols. MSI is an optical imager with 7 channels from visible to thermal infrared and BBR is a radiometer which has the potential to retrieve shortwave and longwave radiation flux. The data from four sensors are analysed synergistically to derive radiative flux profile within 10W/m2 accuracy in cloudy condition.

9241-29, Session 6

Observation planning algorithm of a Japanese spaceborne sensor: Hyperspectral Imager Suite (HISUI)

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Hyperspectral Imager Suite (HISUI) is a Japanese future spaceborne hyperspectral instrument being developed by Ministry of Economy, Trade, and Industry (METI) and will be launched in 2016 or later. HISUI's operation strategic study is described in this paper. In HISUI project, Operation Mission Planning (OMP) team will make long- and short-term observation strategy of the sensor. OMP is important for HISUI especially for hyperspectral sensor with narrow swath of 30 km.

There are two major limitations on the operation of HISUI Hyperspectral Imager. The first one is the maximum observation time per orbit. This is due to the cooling systems of the instrument to keep the instruments temperature within the design requirements. The maximum observation time per orbit is set to 15 minutes as the current baseline. The second one is maximum data downlink amount per day. This is a limitation given by communication link of the satellite bus and heavily depends on the operation of the platform satellite. The current baseline is 150 GB per day for hyperspectral sensor and 550 GB for multispectral sensor.

We have developed observation coverage simulation program and studied the relationship between the limitations of sensor operation and the planned observation scenarios. The achievements of global mapping or regional monitoring need to be simulated precisely before launch.

We have prepared daily global high resolution (30 second in latitude and longitude) cloud coverage data for the simulation. We have processed MODIS cloud mask products (MOD35) of 6 year (2190 days) from 2008 to 2013. We have generated monthly and year averaged value of the image also (Global Monthly Cloud Free Probably Map).

To get more cloud free image in the HISUI operation, we differentiate priority using average CFP (Could Free Probability) map and MCFP (Monthly CFP) map. We have developed 3 types of rules. We gave the higher priority for the area of monthly CFP is higher than the year averaged CFP. (The details of the rules will be show at the presentation.) We used observation simulation tool and have done the simulations of five year from beginning of data acquisition soon after launch. The results shows one the area of observation with best rule of the three acquired 1.3 % more cloud free image comparing with the standard rule.

The results of the simulations shows that HISUI will be able to acquire cloud free image of about 70 % of the terrestrial surface in five years (at the condition of 150 GB/day downlink rate). The detail of the results will be presented at the symposium.

9241-30, Session 7

CNES developments of key detection technologies to prepare next generation focal planes for high resolution Earth observation

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This paper describes the activities managed by CNES for the development of focal planes for next generation High Resolution Earth Observation Satellites, in low sun-synchronous orbit.

CNES has launched a new programme named OTOS, to increase the level of readiness (TRL) of several key technologies for High Resolution Earth Observation satellites, aiming a target GSD of 0.3 m at nadir, and a swath in the range [15 km ; 20 km].

The OTOS programme includes several actions in the field of detection and focal planes: a new generation of CCD and CMOS image sensors, updated analog front-end electronics and analog-to-digital converters.

The main features that must be achieved on focal planes for high resolution Earth Observation are : readout speed, signal to noise ratio at low light level, anti-blooming efficiency, geometric stability, MTF and line of sight stability.

The next targeted steps are presented in comparison to the in-flight measured performance of the PLEIADES satellites launched in 2011 and 2012.

The high resolution panchromatic channel is still based upon Backside illuminated (BSI) CCDs operated in Time Delay Integration (TDI). For the multispectral channel, the main evolution consists in moving to TDI mode and the competition is open with the concurrent development of a CCD solution versus a CMOS solution.

New CCDs will be based upon several process blocks under evaluation on the e2v 6 inches BSI wafer manufacturing line. These new blocks allow to achieve fast output amplifiers, vertical metal interconnect in image area, black coating, field-assisted electrodes for large pixels, and reduced clock levels to reduce power consumption.

New CCD drivers, analog front-end electronics and analog-to-digital converters are also included in this programme aiming to increase operating frequencies and reduce power dissipation.

The OTOS strategy for CMOS image sensors investigates on one hand custom TDI solutions within a similar approach to CCDs, and, on the other hand, investigates ways to take advantage of existing performance of off-the-shelf 2D arrays CMOS image sensors.

We present the characterization results obtained from test vehicles designed for custom TDI operation on several CIS technologies. Two types of pixel architectures were explored: charge transfer architecture also called CCD-on-CMOS and specific architectures to achieve TDI-like accumulation via digital summation.

Three procurement sources for charge transfer TDI on CMOS were characterized in the frame of contracts with e2v, IMEC and ESPROS.

A fourth procurement source for digital TDI was tested in the frame of a contract with ST Microelectronics.

We shall focus on charge transfer efficiency, for CCD-on-CMOS, and lag, for digital TDI, which are the challenging parameters for large pixels architectures.

The analysis of the requirements related to focal planes using off-the-shelf 2D arrays led to the selection of the CMV family developed by CMOSIS, identified as good candidates thanks

to their size, readout speed and shutter efficiency. A summary of results obtained before and after radiation tests will be presented for CMV4000 and CMV 12000.

9241-31, Session 7

Space detector developments at SOFRADIR for sounding applications

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SOFRADIR is one of the leading companies involved in the development and manufacturing of infrared detectors for space applications. Among them, meteorological applications, meaning imagery and spectrometry, require detectors operating from medium wavelength up to high wavelength bands (around 14 µm) while having high radiometric and imaging performances.

The purpose of the paper is to focus on developments made at SOFRADIR in order to answer specific needs of infrared sounding instruments, as for MTG IRS. Analysis of the main driven performances and constraints is presented. Then the proposed designs and solutions are described and first results of the developments in progress are presented.

9241-32, Session 7

Radiation-induced charge transfer inefficiency in charge-coupled devices: Sentinel-4 CCD pre-development as a case study

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Many space telescopes designed for Earth Observation and Astronomy missions operating in the UV, visible or near-infrared wavelengths rely on Charge-Coupled Devices (CCD) to detect and image photon. The performance of a CCD depends on its capability to transfer efficiently the photo-generated charge from pixel to pixel towards a single output node. Due to the high number of pixels, it is imperative to minimize the charge transfer inefficiency (CTI) - the charge packet fraction lost at each transfer. Nowadays scientific CCDs typically achieve CTI performance better than 0.00001. However during operation in space, CCDs suffer from radiation damage gradually increasing CTI. Energetic particles (mostly MeV protons) emitted by the Sun and surrounding the Earth hit the CCD silicon lattice creating defects by displacement damage. These defects act as charge traps that stochastically capture and release the charge during their transfer, distorting the acquired image or spectrum and decreasing the measurement signal-to-noise ratio.

In the last decade, radiation-induced CTI has been identified as a great contributor to the error budget and a potential threat to the science objectives of Astronomy missions performing accurate measurements in the photon-starving regime (e.g., Hubble Space Telescope, Gaia, Euclid). In an effort to mitigate the CTI issue, space agencies, the industry and scientific consortia led dedicated measurement campaigns on irradiated devices, developed models and several corrective data processing techniques as well as hardware countermeasures. More recently Earth Observation missions become also under scrutiny, in particular the Sentinel-4 mission (S-4) due to its geostationary orbit and rather stringent radiometric requirements.

The Sentinel-4 mission (S-4) is part of Europe's Copernicus environmental monitoring programme space component procured by the European Space Agency. S-4 is designed to accurately monitor the composition of the Earth atmosphere above Europe for air quality control purposes. It uses a dedicated Ultra-violet/Visible/Near-Infrared (UVN) spectrometer on-board a Meteosat Third Generation-Sounder (MTG-S) geostationary satellite as well as auxiliary data provided by the MTG satellites. The S-4 UVN spectrometer detectors are two frame-transfer Charge-Coupled Devices (CCDs) custom-made by e2v, each devoted to either the UV-Vis or NIR wavelength ranges (respectively 305-500 nm and 750-775 nm). The first S-4 mission is scheduled for launch in 2020 for 7 years of operation.

E2v conducted a series of measurements using irradiated S-4 breadboard devices as part of the S-4 CCD pre-development.

We present a detailed analysis of e2v's data extracting the CCD CTI performance post irradiation and deriving information about the nature of the traps responsible of the observed CTI. Subsequently we use the reduced test data to derive a charge transfer model representative of the S-4 CCD operation. This model is then used to assess the contribution of radiation-induced CTI to the S-4 spectral radiometric error. Finally we discuss the applicability of generic hardware and software CTI-countermeasures.

9241-33, Session 7

Cryogenic and radiation hard ASIC design for large format NIR/SWIR detector array

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No Abstract Available.

9241-35, Session 8

Comparison of MODIS and PLEIADES Lunar observations

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MODIS has 20 reflective solar spectral bands (RSB), covering wavelengths from 0.41 to 2.3 microns. MODIS RSB are calibrated on-orbit by an on-board solar diffuser. In addition, regularly scheduled lunar observations are made through the instrument space view (SV) port and used to track the RSB radiometric calibration stability. To date, there have been approximately 136 scheduled lunar observations made for Terra MODIS and 110 for Aqua MODIS. For each instrument, the scheduled lunar observations are made at nearly the same phase angles. From time to time, each MODIS also views the Moon through its SV port. These lunar observations are generally collected at different phased angles. The PLEIADES system is composed of two satellites, PLEIADES-1A and PLEIADES-1B launched at the end of 2011 and 2012, respectively. The instruments have 5 reflective solar spectral bands (blue, green, red and near-infrared) with a 2.8 m spatial resolution and a panchromatic channel with a 70 cm vertical viewing resolution. PLEIADES RSB are calibrated based on the observation of Pseudo Invariant Calibration Sites (PICS), such as African desert Sites, Antarctica, Oceans sites and the Moon. One year after the launch of PLEIADES-1B, more than 960 images of the Moon were acquired covering the phase angle range of ±115 degrees, dedicated to its calibration but also to evaluating the sensitivity of calibration methods using the Moon. This paper provides an overview of MODIS and PLEIADES lunar observations and an assessment of their calibration difference using lunar observations made over a range of phase and libration angles. Also discussed in this

paper are strategies and future effort that can greatly benefit other earth observing sensors and potentially improve the radiometric accuracy of existing lunar model(s).

9241-36, Session 8

POLO: a unique dataset to derive the phase angle dependence of the Moon irradiance

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PLEIADES is a dual Earth observation system composed of two satellites, PLEIADES-1A and PLEIADES-1B, respectively launched at the end of 2011 and 2012. This imagery system, led by CNES, has four spectral bands, blue, green, red and near infrared, with a spatial resolution of 2.8 m and a panchromatic band with a resolution of 0.7 m in vertical viewing. Its swath is about 20 km.

In the framework of the PLEIADES radiometric calibration, studies took place in order to determine the calibration precision that could be reached from the acquisitions realized on the Moon. Indeed, the precisions reached from observations of calibration sites on Earth (African deserts, Antarctica, clouds, instrumented sites) are about 2-3% for most of the spectral bands in the visible and the near infrared spectra. It is very difficult to further improve this precision down to 1% because each method has its own limitations, generally due to atmospheric disturbances. In this context, the Moon seems to be an ideal calibration site: there is no atmosphere and its surface properties – thus its optical properties - are perfectly stable.

Taking advantage of the high level of agility of PLEIADES, we performed an intensive observation campaign of the Moon in addition to the nominal acquisitions – when the Moon phase angle is about 40°. This intensive observation of the Moon, named POLO for Pleiades Orbital Lunar Observations, consists of a thousand acquisitions covering the phase angle range ±115 deg. The Moon was acquired as frequently as once every orbit, which represents acquisitions every 100 minutes.

This paper provides an overview of these lunar experiments and an assessment of the variation of the irradiance of the Moon with the phase angle. This paper also discusses a way to improve the phase angle dependence of existing lunar models.

9241-37, Session 8

Introduction to the Sentinel-2 radiometric calibration activities during commissioning phase

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In partnership with the European Commission and in the frame of the Copernicus program, the European Space Agency (ESA) is developing the Sentinel-2 optical imaging mission devoted to the operational monitoring of land and coastal areas.

The Sentinel-2 mission is based on a satellites constellation deployed in polar sun-synchronous orbit. Sentinel-2 will offer a unique combination of global coverage with a wide field of view (290km), a high revisit (5 days with two satellites), a high spatial resolution (10m, 20m and 60m) and multi-spectral imagery (13 spectral bands in visible and shortwave infra-red domains). The first satellite is planned to be launched in mid 2015.

In this context, the Centre National d'Etudes Spatiales (CNES) supports ESA to insure the cal/val commissioning phase during the first six months in flight.

This paper provides first an overview of the Sentinel-2 system and a description of the products delivered by the ground segment associated to the main radiometric specifications to achieve.

Then the paper will focus on the description of the Sentinel-2 Technical Expertise Center which is in charge of the radiometric and geometric activities during the commissioning phases of the Sentinel-2 satellites.

The paper will finally address the radiometric methods and calibration sites used in this CNES image quality center to reach the specifications of the sensors, in term of absolute calibration, pixel to pixel relative sensitivity, MTF estimation and level 2 products accuracy.

9241-38, Session 8

Cross-calibration of the RapidEye Multispectral Imager payloads using near simultaneous acquisitions of pseudo-invariant test sites

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Radiometric calibration of the RapidEye Multispectral Imager (MSI) and other remote sensing imaging systems is an essential task in the quantitative assessment of sensor image quality and the production of reliable data products for a wide range of geo-spatial applications. Spatially and temporally pseudo-invariant terrestrial targets have long been used to characterize Earth observation systems and provide a consistent record of their radiometric performance. This study focuses on the use of near-simultaneous acquisitions of calibration test sites by all of the RapidEye multispectral imagers (MSI) as a means to track the relative radiometric stability of the five sensors in the constellation. As the cameras acquired the sites with different image acquisition and solar illumination parameters a compensation factor is derived to account for the site bidirectional-reflectance-function (BRDF) variations that occur with different sun-target-sensor acquisition conditions. The derived top-of-atmosphere reflectance is computed as a figure of merit to measure and track the constellation response to each of the test sites. The results show that the differences between the same bands on the different spacecraft are much smaller than what BlackBridge promises in the RapidEye product specifications.

9241-39, Session 8

Three-year operation of in-orbit radiometric calibration for geostationary ocean color imager

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Geostationary Ocean Color Imager (GOCI) onboard COMS(Communication, Ocean and Meteorological Satellite) spacecraft is the first spaceborne imager for ocean color remote sensing in Geostationary Earth Orbit (GEO). Over the three years, GOCI has been in on-orbit normal operation since its launch in June 2010. For the fulfillment of ocean color monitoring mission, GOCI equips 8 spectral bands. In visible wavelength region from 40 2nm to 685 nm, 6 spectral bands are implemented on GOCI with the bandwidth of 20 nm (for B1 ~B5) or 10 nm (for B6, central wavelength at 680 nm). Two spectral bands located in NIR wavelength region with band center at 745nm and 865 nm are mainly used for the atmospheric correction. Thanks to the satellite location in geostationary orbit, GOCI can acquire the image from Earth

with staring capture method with 2D CMOS FPA (Focal Plane Array). Instantaneous Field of View(IFOV) of GOCI is about 700 km x 700 km with 500 m spatial resolution over the center of the coverage area (130˚E, 36˚N). Because the user-required observation coverage area is 2,500 km x 2,500 km which includes the region of Korean Peninsula, East China, and Japan, 4 x 4 slot image acquisitions which corresponds to IFOV are required for the image acquisition for the coverage area including overlap region among slot images. In-orbit calibration activities of GOCI have mainly been performed using onboard Solar Diffuser (SD) and Diffuser Aging Monitoring Device (DAMD) equipped in the Shutter Wheel Assembly (SWA) on the top panel of the instrument. SD and DAMD of GOCI are QVD (Quasi-Volume Diffuser) type solar diffusers made of fused silica (SiO2). DAMD which has a purpose to monitor the in-orbit performance degradation of SD is identical to SD except for the size. The diameter of SD and DAMD are 14 cm and 7 cm, respectively. GOCI radiometric model which converts raw data recorded in DN (Digital Number) to physical unit (in the case of GOCI, it is radiance with the unit of W/m2/?m/sr) is defined with 3rd order polynomial with no quadratic term. Linear gain (G) and 3rd order non-linear gain (b) in GOCI radiometric model can be acquired from the calibration images observed with SD and DAMD at local night time. In this paper, we present the in-orbit radiometric calibration status of GOCI during first three years of operation. Annual sinusoidal variation of GOCI radiometric gains due to the diffuser transmittance variation with respect to the solar incident angle on azimuth direction is mainly discussed. Existing in-orbit calibration data shows that GOCI radiometric performance is stable with 0.3 % variation for three years.

9241-40, Session 9

Effects of Lambertian sources design on uniformity and measurements

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The effects of generic sphere design assumptions on radiometric uncertainty are examined. Next we look at these generic assumptions on sphere-design versus applied uniformity mapping techniques and make comparison of different fields of view, design permutations and effects on uniformity and uncertainty. Uniformity in broad spectrum and spectral bands are explored. We discuss macro and micro mapping techniques and results as a function of observed uniformity as well as laboratory testing results customized to match with customer's instrumentation field of view. We will also discuss our initial traceability system characterization effort and recommendations with basic commercial instrumentation, as well as advanced techniques we have used to validate, inspect, and improve on our results in reducing uncertainty of uniform source measurements.

9241-41, Session 9

Evaluating performances of vacuum dedicated blackbodies

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Vacuum blackbodies have to combine performance of traditional infrared reference sources with specific features in order to operate in vacuum chamber, at cryogenic or ambient temperatures. Their usual applications are calibration and tests of IR sensors to be loaded on satellites, earth or space radiation simulation and test of IR sensors for scientific applications. They are consequently designed for very demanding users.

Consequently, emission over an ultra extended temperature range, knowledge of the radiated temperature with a high accuracy, extremely high uniformity of the emissive surface and extremely high emissivity are usual features of vacuum blackbodies.

Such blackbodies consist in a vacuum compatible emissive head connected to a controller located out of the chamber. High stability of regulation must be ensured by an optimized control of the losses through radiation and conduction.

The current paper describes two models of vacuum blackbodies and shows methods to evaluate the extreme performances of such sources.

The first blackbody is a cavity type blackbody with a specified emissivity of 0.999. As accurately measuring such a high emissivity is impossible using existing emissometers, HGH developed a method to evaluate the emissivity of such a blackbody. This method combines a classic measurement of emissivity on a sample and a mathematical simulation.

The second blackbody is an extended area source with also an extended temperature range. The paper demonstrates that the operating specifications of this source (minimum/ maximum temperature, warm up and cooling time, power and cooling fluid consumption, etc.) highly depend on the radiated optical signal from the environment (other instruments, chamber wall temperature). Measured results validate the theoretical estimations of these specifications.

Thanks to its long experience in high-end applications of blackbodies, HGH is able to supply but also demonstrate the specifications of vacuum dedicated blackbodies.

9241-42, Session 9

Ground testing and campaign intercomparisons with the NAST-I airborne FTS

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The NASA / NPOESS Airborne Sounder Testbed - Interferometer (NAST-I) is a well-proven airborne remote sensing system used to support satellite system calibration / validation and Earth system science. This presentation will focus on post-mission ground testing and campaign intercomparisons from the recently conducted Suomi NPP (SNPP) airborne field campaign.

9241-43, Session 9

Calibration and validation activities for DubaiSat-2 performance assessment

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DubaiSat-2 is United Arab Emirates (UAE) second earth observation satellite. It was launched into a 600 km orbit on the 21st of November 2013. After Satellite Stabilization, the Calibration and Validation (Cal/Val) for DubaiSat-2 performance assessment has been proceeding along with the implementation of DubaiSat-2's image data processing system in the Emirates Institution for Advanced Science and Technology (EIAST). The aim of the Cal/Val activities is to ensure and to fulfill the image quality standards that were agreed on and previously measured in the lab. Aiming for high standards always assure a good visualization of the image and a better product to satisfy the market demand. This phase extended over the period of 25/11/2013 till 28/02/2014. This phase included most of the relative calibration tasks, pointing accuracy, color balancing and bands registration. This paper will include the analysis and the procedure that was considered while evaluating the different image quality assessment parameters, such as Ground Sampling Distance (GSD), Signal-to-Noise Ratio (SNR), Modulation Transfer Function (MTF), Band-to-Band Registration, Offset Measurements, Digital Elevation Model (DEM) and Non-Uniformity Correction (NUC).

9241-45, Session 9

Prelaunch calibrations and on-orbit performance analysis of FY-2D SVISSR infrared channels

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Meteorological satellites have become an irreplaceable weather and ocean observing tool in China. These satellites are used to monitor natural disasters and improve the efficiency of many sectors of Chinese national economy. It is impossible to ignore the space-derived data in the fields of meteorology, hydrology, and agriculture, as well as disaster monitoring in China, a large agricultural country. For this reason, China is making a sustained effort to build and enhance its meteorological observing system and application system. The first Chinese polar-orbiting weather satellite Feng-Yun (FY-1A) was launched in 1988. Since then China has launched 12 meteorological satellites, 6 (FY-1A/B/C/D and FY-3A/B) of which are sun synchronous and 6 of which (FY-2A/B/C/D/E/F) are geostationary satellites; China will continue its two types of meteorological satellite programs. FY-2A satellite is the first geostationary meteorological satellite developed by China. FY-2 series satellites are cylinders with 2.1m in diameter and 1.6m in height, the total height include antennas is 3.1m. The weight is about 600kg and the spin-mode stabilization is in use. Its rotating speed is 100±1 per minute. Their designed lifes are 3 years.

FY-2D and FY-2E was the 4th and 5th satellite of Fen-Yun 2 series geostationary satellites which have successfully launched on Dec. 8, 2006 and Dec. 23, 2008 respectively. With the launch of FY-2D, Chinese geostationary meteorological satellite observing system formed the first binary mode which can provide 15-minute interval of the cloud zone animation during the flood season in China, greatly improving the timeliness of meteorological satellite cloud images. FY-2E was launched and planned to take the place of FY-2C. After the in orbit testing period, FY-2D was operationally running from February 14, 2007 at 86.5 º E above the equator. FY-2E was moved to 105 º E above the equator on Nov. 24, 2009 and replaced FY-2C operationally. SVISSR is the main payload onboard FY-2D/E satellites and collects data in 5 spectral bands, which are located, according to their wavelengths, on two focal plane assemblies (FPAs): visible and infrared. The visible FPA, which have no temperature control and thus vary with the instrument temperature, is referred to as the warm FPA. The infrared FPA is the cold FPA (CFPA) with their on-orbit temperature nominally controlled at 93.5K and 100.5K separately depends on the seasons.

In order to maintain data quality over its entire mission, an onboard BB was designed for the TEB calibration. To achieve this objective, extensive prelaunch calibration and characterization measurements were also made using a ground based BB calibration source (BCS). SVISSR TEB prelaunch radiometric calibration was performed at different instrument temperature levels which were referred to as the cold, nominal, and hot plateaus, and at different CFPA temperatures. 14 measurements of different temperature groups of key optics were made at the CFPA temperature set at 93.5 K and 100.5 K. During sensor thermal vacuum radiometric calibration, the BCS temperatures varied from 180 to 340 K for TEB detector noise, dynamic range, and nonlinearity characterization. The OBC BB was controlled at fixed temperature 288 K for gain and offset characterization. The onboard BB was designed to be temperature controlled at fixed 288 K via a pair of electrical elements. The dynamic range of the OBC BB thermistors was carefully designed to cover this temperature range. Prelaunch measurements showed that all thermistors met this requirement. Based on prelaunch characterization, the calibration differences among individual thermistors was small and, therefore, no special effort was made to correct for these differences.

The range of FY-2D/E SVISSR thermal channels is from 10.4 ?m to 12.5 ?m. During on-orbit calibration, the average temperature from all 4 thermistors is used as the representative temperature for the onboard BB. Using the average has significantly reduced the random errors due to telemetry noise from individual thermistors. The onboard blackbody was very stable for two satellites. Since FY-2D was launched on Dec. 8th, 2006 and thermal infrared channel started to collect data on Jan. 4th, 2007, the downstream OBC BB temperatures monitoring data from satellite were collected every half an hour. The OBC BB was very stable during the on-orbit operation from early 2007 to now. The temperature of the OBC BB was always stable at 14.6482 degree C except some decode error data. And the same to FY-2E except the OBC BB temperature was stabilized at 19.8792 degree C. The cold FPA performance, detector noise characterization and the telemetry data of some key optical components were also demonstrated and analyzed in this research.

9241-46, Session 10

Concepts for a geostationary-like polar missions

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The recently issued eighth annual ‘Arctic Report Card’ noted that “the effects of a persistent warming trend that began over 30 years ago remain clearly evident” and that this trend is influencing the Arctic’s terrestrial and marine ecosystems [1]. The considerable change that has occurred in the Arctic, along with the concept of ‘Arctic Amplification’, and its largely anthropogenic origins is widely accepted. However, consensus remains absent as to the impact of these changes within the cryosphere on northern mid-latitudes, the broader global climate, and the mechanism which links them [2–7]. In [7], it is suggested that reductions in sea-ice impacts atmospheric circulation, with reduced upper-level zonal winds at high-latitudes causing increased amplification resulting in stagnant weather patterns. However, the underlying mechanism for this linkage is not detailed and any link remains hypothetical. These uncertainties, along with the potentially global impact accentuate the current disparity between the breadth and depth of observations available for the tropics and mid-latitudes with the lack of geostationary-equivalent observations over the polar regions.

A geostationary-like polar observing system will enable the collection of all possible clear-sky pixels to radically improve key polar observations, including resolution of the diurnal cycle of phenomena related to, amongst other things, winds, clouds, sea ice, snow cover, and sea surface temperature. Analysis of such phenomena will enable improved weather forecasting and modelling, along with environment modelling due to the high-quality continuous observations enabled. It will also significantly improve monitoring of ‘Essential Climate Variables’ (ECVs), improving understanding of climate change and modelling of associated feedback processes.

Furthermore, as the Polar Regions are undergoing rapid environmental change this, in the Artic in-particular, is creating new commercial opportunities that in-turn produce new pressures on the environment. A comprehensive polar observing system would enable monitoring of commercial actives and their environmental impact. Summer ice melt is also creating new pressures on existing infrastructure, and the Northwest Passage is becoming ever more accessible as a summer shipping route, which will in-turn lead to a further general increase in economic activity and a potentially significant growth in surface, air and marine traffic. As such, the current commercial Earth Observation market demand will spread to the poles, where currently it cannot be fully serviced.

This paper summarises an on-going European Space Agency study into mission concepts for geostationary-like polar observation systems. The paper develops an evidence-led scientific case for further development of a space-based polar remote sensing platform at geostationary-like altitudes. The scientific case considers the impact of observation from a highly elliptical orbit on meteorological and climatological requirements currently addressed from polar-orbiting instruments, and the impact of orbit inclination to differentiate the use of natural critical-inclination orbits, e.g. Molniya orbits, from Taranis orbits to assess if Taranis orbits add significant extra value to a natural critical-inclination orbit [8–12]. The paper also presents a mission and system design of the down-selected polar observation system, with a focus on the instrumentation payload, conducting an analysis of the effect of the orbit, specifically its eccentricity and radiation environment, on the spacecraft technology.

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9241-47, Session 10

SkySat-1: very high-resolution imagery from a small satellite

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No Abstract Available

9241-48, Session 10

DEIMOS-2: cost-effective, very-high resolution multispectral imagery

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Elecnor Deimos is a private Spanish company, part of the Elecnor industrial group, which owns and operates Deimos-1, the first Spanish Earth Observation satellite. Deimos-1, launched in 2009, is among the world leading sources of high resolution data.

Elecnor Deimos will launch in Q2 2014 its second satellite, Deimos-2, which will be a very-high resolution, agile satellite capable of providing 75-cm pan-sharpened imagery, with a 12km-wide swath. The Deimos-2 camera will deliver 3-m multispectral imagery in 4 bands: G, R, B and NIR.

Deimos-2 is only the third European commercial satellite, and the first one completely owned by private capital, capable of providing sub-metric multispectral imagery.

The whole end-to-end Deimos-2 system has been designed to provide a cost-effective and highly responsive service to cope with the increasing need of fast access to very-high resolution imagery. It will be operated, with a 24/7 commercial service, by Elecnor Deimos Imaging, the subsidiary of Elecnor Deimos which has been operating the Deimos-1 satellite since its launch.

The Deimos-2 satellite has been co-developed by Elecnor Deimos and SATREC-i (South Korea), based on the SpaceEye-1 platform design, and it has been integrated and tested in the new Elecnor Deimos Satellite Systems premises in Puertollano (Spain).

The ground segment, which includes two receiving/commanding ground stations in Spain and one in Norway, has been completely developed in-house by Elecnor Deimos, based on its gs4EO suite.

In this paper we describe the main features of the Deimos-2 system, with emphasis on its initial operations and the quality of the initial imagery, and provide updated information on its mission status.

9241-49, Session 10

THE DUBAISAT-2/DEIMOS-2 constellation: public-private cooperation between Emirates and Spain

Julio C. Lopez Bravo, Fabrizio Pirondini, Elecnor Deimos Imaging S.L. (Spain)

The Emirates Institution for Advanced Science and Technology (EIAST) was established by the Dubai Government in 2006 with the goal of promoting a culture of advanced scientific research and technology innovation in Dubai and the UAE, and enhancing technology innovation and scientific skills among UAE nationals. EIAST launched in November 2013 the DubaiSat-2, its second Earth Observation satellite, and the first to provide VHR multispectral imagery. The satellite has successfully completed its in-orbit commissioning and it is now

fully operational.

Elecnor Deimos is a private Spanish company, part of the Elecnor industrial group, which owns and operates Deimos-1, the first Spanish Earth Observation satellite, launched in 2009. Elecnor Deimos will launch in Q2 2014 its second satellite, Deimos-2, a very-high resolution, agile satellite capable of providing 4-bands multispectral imagery. The whole end-to-end Deimos-2 system has been designed to provide a cost-effective and highly responsive service to cope with the increasing need of fast access to VHR imagery.

The two satellites, with a mass of 300 kg each, were developed in cooperation with SATREC-i (South Korea), and are based on the SpaceEye-1 platform. The two satellites have an identical payload, and produce 75-cm resolution pan-sharpened imagery across a 12-km swath. Together, they have a combined collection capacity of more than 300,000 sqkm per day.

EIAST and Elecnor Deimos have set up a unique, trans-national public-private partnership to operate the two satellites as a constellation, jointly commercialize the imagery of both satellites, and interchange technical and operational information to increase the efficiency of both systems.

The operations of the constellation are based on three ground stations: Al Khawaneej (Dubai), Puertollano (Spain) and Svalbard (Norway), which assure at least a contact per orbit with each satellite. The constellation functionalities of the ground segment were developed by EIAST and Elecnor Deimos in cooperation, in order to provide a product which is exactly the same, independently of which satellite acquired the image.

This paper describes the main features of the Dubaisat-2 and Deimos-2 systems, their combined use in constellation, and the products and services jointly offered to public and private customers worldwide. Moreover, it describes the cooperation agreement between EIAST and Elecnor Deimos, and provides an update of the operational status of both missions at the time of writing.

9241-50, Session 11

A compact thermal infrared imaging radiometer with high spatial resolution and wide swath for a small satellite using a large format uncooled infrared focal plane array

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In this paper, we present a feasibility study for the potential of a high spatial resolution and wide swath thermal infrared(TIR) imaging radiometer for a small satellite using a large format uncooled infrared focal plane array (IR-FPA). An uncooled IR-FPA is one of infrared detectors of an emerging technology developed in recent years, and is widely used in low cost military and civilian applications like night visions, survey cameras, thermal cameras, etc. Furthermore, recent progress of MEMS technology enables high-resolution and large format devices. The uncooled IR-FPA also carries the advantage that no cooling system such as a mechanical cooler is required. Eliminating cooling systems from the TIR imaging radiometer can reduce the size, cost and electrical power consumption of the TIR imaging radiometer. Although sensitivity of the uncooled IR-FPA is less than that of HgCdTe based detector arrays, the advantage of it without cooling systems is suitable for space applications, small satellites or resource limited systems.

A feasibility study of such a radiometer for a small satellite was carried out. The preliminary TIR imaging radiometer designs were performed. One is a single band imaging radiometer (8-12μm) with a large format 2000 x 1000 pixels uncooled IR-FPA with a pixel pitch of 15 μm. The other is a multi-band imaging radiometer in the thermal infrared wave bands (8.8μm, 10.8μm, 11.4μm). This radiometer is employed separate optics and detectors for each wave band. It is based on the use of a 640 x 480 pixels uncooled IR-FPA with a pixel pitch of 25 μm. The thermal time constant of an uncooled IR-FPA is approximately 10-16ms, and introduces a constraint to the satellite operation to achieve better signal-to-noise ratio, MTF and linearity performances. In other words, a sampling time must be longer than the thermal time constant. The study addressed both on-ground time-delay-integration binning and staring imaging solutions, although a staring imaging was preferred after trade-off. The staring imaging requires that the line of sight of the TIR imaging radiometer gazes at a target area during the acquisition time of the image, which can be obtained by rotating the satellite or a steering mirror around the pitch axis. The single band radiometer has been designed to yield a 30m ground sample distance over a 30km swath width from a satellite altitude of 500km. The radiometric performance, enhanced with the staring imaging, is expected to yield a NETD less than 0.5K for a 300K ground scene. The multi-band radiometer has three spectral bands with spatial resolution of 50m and swath width of 24km. The radiometric performance is expected to yield a NETD less than 0.85K.

We also showed some preliminary simulation results on wildfire, volcano, lake, desert and fields scenes using thermal infrared images obtained by a thermal sensor on airplane.

9241-51, Session 11

PanelSAR, an affordable small satellite miniSAR radar in support of infrastructure surveillance

Pieter van Duijn, SSBV Aerospace & Technology Group (Netherlands)

In the world today, the lack of knowledge on the condition of critical infrastructure (roads, bridges, buildings, large structures, dikes and other natural defenses) is a major problem.

This applies not only in areas threatened by hazards such as earthquakes or flooding, but also in any area where the proper functioning of society depends on the stability and reliability of infrastructure. As can be seen from many recent disasters and catastrophic events, their impact could have been significantly reduced, or in some cases prevented, if only a proper awareness of the infrastructure state was available.

Based on work performed using Synthetic Aperture Radar (SAR) data from a number of large satellite platforms, models and algorithms to support the measurement of changes over time (deformation) have been developed and successfully demonstrated. A wide deployment of such services has, however, not been achieved to date. This is partly due to the costs, partly due to the orbit (revisit time) and availability of data for repeating areas and targets.

In recent years, small satellites have started to play an increasingly important role in the implementation of Earth Observation systems. Given their price-performance and reliability, smallsats have also become the solution of choice for decision makers and investors, even more so given decreasing budgets and economically constrained investments.

PanelSAR is a smallsat-optimised Synthetic Aperture Radar instrument. With its flexible architecture, it suits different platforms and mission profiles. In combination with a smallsat platform and a proper selection of observation parameters, such as resolution and revisit time, as well as a precise identification of the observation area, it presents a unique and unprecedented means to achieve wide-scale or optimized-area infrastructure monitoring.

So far associated with large, complex and primarily institutional or military satellites, SAR from space was too expensive to serve in low-cost, narrowly-focused mission. The PanelSAR concept is an enabler of space-SAR missions for exactly this purpose.

The PanelSAR instrument is based on a combination of proven airborne SAR technology, low-power SAR principles (FMCW / iFMCW) and the use of a mix of commercial and next

generation space technology. This has led to a capable, yet affordable SAR sensor and an equivalent end-to-end smallsat solution.

The paper describes the concept of the first PanelSAR Flight Demonstration mission to present its technical capabilities and more specifically, its ability to perform infrastructure monitoring. The background to the PanelSAR concept and technology is presented, along with examples of use cases, especially for deformation monitoring.

About SSBV

The SSBV Aerospace and Technology Group is a Dutch-owned group of SME's with almost 30 years of experience in the space industry. SSBV adopts a product-based engineering and development approach to design and provide component, subsystem and system solutions. The SSBV portfolio covers a full scope of EGSE, TTC and High-Rate Ground Station Solutions, RF subsystems, On-Board computing and processing as well as smallsat sensors and subsystems. As part of a Dutch national technology program, SSBV and its partners have been developing PanelSAR since 2011.

9241-52, Session 11

Design, simulation and test of silicon immersed gratings : key to compact spectrometers in the short-wave infrared

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We present results of our integrated approach to the development of novel diffraction gratings. At SRON we manufacture prism-shaped silicon immersed gratings. Diffraction takes place inside the high-refractive index medium, boosting the resolving power and the angular dispersion. This enables highly compact spectrometer designs. We are continuously improving the cycle of design, simulation and test to create custom gratings for space and ground-based spectroscopic applications in the short-wave infrared wavelength range. Applications are space-based monitoring of greenhouse and pollution gases in the Earth atmosphere and ground-based SWIR spectroscopy for, a.o., characterization of exo-planet atmospheres.

We make gratings by etching V-shaped grooves in mono-crystalline silicon. The groove facets are aligned with the crystal lattice yielding a smooth and highly deterministic groove shape. This enables us to predict the polarized efficiency performance accurately by simulation. Feeding back manufacturing tolerances from our production process, we can also determine reliable error bars for the predicted performance.

Combining the simulated values for polarized efficiency with ray-tracing, we can optimize the shape of the grating prism to eliminate unwanted internal reflections.

In this contribution we present the architecture of our design and simulation platform as well as a description of test setups and typical results.

9241-53, Session 11

Lightweight ZERODUR® mirror blanks: recent advances supporting faster, cheaper and better spaceborne optical telescope assemblies

Tony B. Hull, The Univ. of New Mexico (United States); Thomas Westerhoff, SCHOTT AG (Germany)

While there is no single material solution ideal for all missions, recent advances by SCHOTT in fabricating lightweight mirror blanks makes ZERODUR® a highly viable solution for many spaceborne telescopes. ZERODUR® is a well-characterized very low-expansion material. Monolithic mirrors are made without bonding or fusing out of highly homogeneous and isotropic blanks currently available in sizes up to 4m plus. We will summarize results recently given in a series of papers on the characteristics of these lightweight mirror blanks in sizes from 0.3m up, and describe the method of blank fabrication, with its compatibility to contemporary optical fabrication techniques that control of all optical spatial frequencies. ZERODUR® has a 35 year heritage in space on numerous missions, including the secondary mirror of Hubble, and all the Chandra mirrors. With the lightweighting we will discuss, ZERODUR® is now a high performing, affordable and rapidly produced mirror substrate suitable for lightweight imaging telescopes.

9241-54, Session 11

Monolithic diffraction grating elements for remote sensing applications

Tobias Moeller, Peter Triebel, Torsten Diehl, Carl Zeiss Microscopy GmbH (Germany); Alexandre Gatto, Lars H. Erdmann, Alexander Pesch, Matthias Burkhardt, Alexander Kalies, Carl Zeiss Jena GmbH (Germany)

A diffraction grating is the vital component of spectral imaging spectrometers. Spectral imaging systems lead to enhanced remote sensing properties when the sensing system provides sufficient spectral resolution to identify materials from its spectral reflectance signature. The performance of diffraction gratings provide an initial way to improve instrumental resolution. Thus, subsequent manufacturing techniques of high quality gratings are essential to significantly boost spectral performance.

ZEISS has developed advanced fabrication techniques to manufacture monolithic, high groove density gratings with low stray light, high diffraction efficiency and low polarization sensitivity characteristic. Gratings at ZEISS can be generated holographically in combination with ion beam plasma etching to enhance the grating profile or made by using gray-scale laser lithography technology.

Holographic recording in combination with plasma etching enable the fabrication of various grating profiles to optimize efficiency including polarization behavior. Typical profile shapes are blazed type gratings, sinusoidal profiles and binary profiles allowing to optimize efficiency and polarization requirements exactly towards the required spectral range. Holographic gratings can be fabricated on plane and curved (convex, concave or free-form shape) substrates.

As grating manufacturing techniques continue to cope with the challenges of enhanced remote sensing capabilities, ZEISS also can pattern large-area diffraction gratings with high resolution in the visible and shortwave infrared by using gray-scale lithography.

In this paper we report on the techniques for the holographic recording of high groove density plane and curved blazed gratings. We show a typical manufacturing process for the fabrication of plane, blazed diffraction grating elements to be used in aerial and satellite imaging systems with specific focus on efficiency and stray light characterization. The ZEISS diffraction grating technology will enable the development of high spectral resolution and compact spectral imaging instrumentation.

9241-55, Session 11

Bandpass filter arrays patterned by photolithography for multispectral remote sensing

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Optical remote sensing of the earth from air and space typically utilizes several channels in the visible and near infrared spectrum. Thin-film optical filters are applied to select these channels. Filter wheels and arrays of discrete stripe filters mounted in frames are standard configurations. To achieve compact and light weight camera designs multi-channel filter plate assemblies can be mounted close to the electronic detectors.

Optics Balzers has developed a photolithographic structuring process based on multiple coating and structuring on the same substrate. High-performance band pass filters are applied by plasma assisted evaporation (plasma IAD) with APS technology and optical broad-band monitoring. This technology has already proven for various MSI configurations on fused silica and sapphire substrates for remote sensing applications.

In the past the optical filter design and performance were limited mainly by the maximum coating thickness structurable by photolithographic lift-off process and by the thermal and radiation load during the process on the photolithographic masking material.

Recent progress in image resolution and sensor selectivity requires improvements of optical filter performance. Blocking in the UV and NIR and in between the spectral cannels, in-band transmission and filter edge steepness have to be subject of further development. Technological limits of the IAD coating accuracy can be overcome only by more precise coating technologies like plasma assisted reactive magnetron sputtering (PARMS) in combination with optical broadband monitoring.

We will present an overview about concepts and technologies for band-pass filter arrays for multi-spectral imaging. Recent performance improvements of filter arrays made by photolithographic structuring with enhanced blocking and improved transmission levels will be presented. The challenges and results achieved for structured filters made by sophisticated coating technologies will be presented.

9241-72, Session PS

The method of improving the spatial resolution of the matrix spectrometer

Yury Krot, Leonid V. Katkovsky, Boris Beliaev, Belarusian State Univ. (Belarus)

Aerospace Researches Department of the Institute of Applied Physical Problems at the Belarusian State University has developed videospectral system intended for ecological space experiment on the board of the ISS. The system includes three matrix based spectrometers MP-15, color (RGB) photocamera and the video-tracking camera. The capabilities of this system are registration of color images of high spatial resolution and about 250 spectra per one image taking simultaneously through a common lens and electromechanical shutter.

The polychromators of every spectrometer includes the imaging fiber, the entrance slit, concave holographic diffraction grating, and photodetector CCD-matrix. Light is sent to the polychromators through an imaging fiber. Input of the imaging fiber is located at the focal plane of the input lens whereas its output is located at the entrance slit.

Astigmatism is typical aberration of polychromators based on concave spherical gratings – rays in the meridional and in the sagittal planes are focused at different points.

It was measured that astigmatic line segment in photodetector plane is 2 mm and height of the entrance slit is 20 mm. This means that polychromator provides about only 10 spectra of spatially separated areas.

The experiment to achieve the highest possible spectral resolution and high spatial resolution for selected optical scheme has been made. Imaging fiber at entrance slit fills the entire height of the slit. Laser radiation was directed to the input of the fiber. He-Ne laser has been used for localization of known spectral line. Complete filling the aperture of the grating by light was controlled. The focusing of spectral lines was achieved by using the shifts of grating.

The image of test-mira with black and white lines illuminated by halogen lamp has been formed at the input of fiber for estimate spatial resolution along the slit. Thus a periodic structure of the brightness distribution has been derived on the entrance slit of the polychromator.

Proposed method of obtaining high spatial resolution without loss of spectral resolution consists in a shift of the output of the imaging fiber on specified distance from the entrance slit along the optical axis. This allows to match the focuses of the rays in the meridional and in the sagittal planes. Entrance slit operates as one-dimensional aperture to obtain high spectral resolution.

Laboratory experiments showed a significant improvement (up to 10x) of spatial resolution determined by the astigmatic grating for the central area of the entrance slit, but the spatial resolution is not uniform along the entrance slit. In areas away from the optical axis, it is worse. Measurements of spectrometer spatial resolution were performed along the entire height of the entrance slit. Measurements showed that the use of this method allows to get more than 80 spatially separated spectra from one polychromators. The width (3 mm) of the imaging fiber provides the complete filling workspace grating. Spectral resolution of this spectrometer is at least 5 nm for wavelength region of 400-950 nm.

9241-74, Session PS

Features of design and development of the optical head of star tracker

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At present Kazakhstan pays great attention to the issues related to development of space industry. Planned launches of spacecraft for the remote sensing stimulate the design and development of own domestic components for spacecraft. This article describes the approach to design of the optical head of star tracker and necessary processes that have been carried out during the development of star tracker engineering model.

At the first stage it was defined the requirements to the optical system of star tracker, that was formed on the fact that the software of star tracker must determine the angular position of satellite with high accuracy. As a result, the following key requirements were determined for the optical system: the field of view should be not less than 20 degrees, the maximum star magnitude is 5.5, the minimum angle between the optical axis and the Sun (exclusion angle) is 40 degrees, dimensions of optical head with the blend is 200x200x300 cubic mm. Furthermore, on the base of analysis of results of star image simulation in CMOS matrix with the account of quantum noise and electronic noise in conjunction with the filtered image it was determined that the image of each star should be defocused in the form of the spot with the diameter of 5-6 pixels. In this case, the physical dimensions of the star image on the matrix are not more than 96 microns. The point spread function is selected so that the diameter of spot with 85% of energy covers about 3 pixels, that allows to determine the centroid (position of the spot center of mass) with sub-pixel precision.

At the second stage it was carried out the preliminary design of the optical system. Requirements developed for the optical head made it necessary to consider the multiple-lens system as a variant of optical system. Three variants of optical system was considered for selection of the optical scheme: seven-lens, six-lens and five-lens optical systems. Design and calculation was carried out for each variant with the help of ZEMAX software system. The change of point spread function and the form and diameter of spot of confusion for various FOVs and concentration of radiant energy in the spot of confusion was studied in the process of calculations. The best results were

obtained for the six - lens optical system.

At the third stage it was developed the engineering model of optical system on the base of its design specifications. For the control of quality of development of optical system components (lens polishing, compliance with their geometrical parameters, accuracy of installation of the optical system elements) it was used the shadow device, autocollimating device, instrument for measuring of skew, thickness indicator. As result of measurements it was determined that the tolerances for specifications of lenses were held. The measured values were processed in ZEMAX software. Analysis of characteristics of developed optical system showed that it satisfies the requirements for the size of spot of confusion.

At the last stage it was carried out the design and development of the blend for star tracker. Modeling of unwanted exposure due to the Sun for the ultimate exclusion angle (40 degrees) was carried out in Matlab in the process of blend design. Since the surface of the blend is divergent the Monte Carlo method was used when modeling - the direction of the further spread of "photon" after next reflection is chosen randomly with a distribution of direction probability, which depends on the properties of the coating surface. According to the results of simulation analysis it was manufactured the blend for optical system.

Engineering model of the optical head developed in accordance with the above approach satisfies all functional requirements and can be used for the development of the star tracker for satellite.

9241-75, Session PS

Plastic optical fiber level measurement sensor based on side holes

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Plastic optical fiber level measurement sensor based on in-line side holes is investigated theoretically and experimentally. The Sensor consists of the plastic optical fiber with in-line side holes spaced by 5 Cm. The 0.6 diameter in-line side holes were fabricated by micro-drilling. An analytical expression of the sensor transmittance was obtained using a simple ray optics approach. The measurements of the sensor transmittance were performed with a 55 Cm height Mass cylinder. Both results show that the sensor transmittance increases as the number of side holes filled with water increases. The research results indicate that the plastic optical fiber based on in-line side holes can be used for water level measurement.

9241-76, Session PS

The effective area calibration precision analysis of grazing incidence soft x-ray optical system

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The grazing incidence soft X-ray optical system is the core equipment of future space science missions, such as the space-based astronomical observations, space environment monitoring and deep space exploration and navigation. The optical system expands the collecting area of X-ray photons and improves the SNR. The effective area of the optical system is the product of the geometrical optical area and the reflectivity of the lens, which reflects the collecting capability of the grazing incidence optical system for the soft X-ray photons. Therefore, the effective area calibration is the key indicator for testing and verifying the performance of the grazing incidence optical system. One of the traditional grazing incidence optical system calibration methods uses the wide beam as the calibration X-ray source. By comparing the count rates of the photon counting detectors at the entrance and the focus point of the optical system achieves the effective area calibration of the optical system. This calibration method requires large ground equipment, high environmental conditions but the X-ray beam is not so parallel that the calibration accuracy is limited. Another effective area calibration method uses the narrow X-ray beam scan the optical system. Progressive scan and record the count rates of the X-ray detectors and the effective area of the optical system obtained by splicing. The narrow X-ray beam is with high degree of parallel, which reduces the volume of the ground calibration equipment. In this paper, the above two calibration methods of the grazing incidence optical system effective area are modeled mathematically and both the two calibration methods are proved to be equivalent with the original definition of the effective area. The factors such as the calibration source beam parallelism, the uniformity of the beam and the relationship between the calibration source and grazing incidence optical system are absorbed into the unified mathematical model for describing the performance of the effective area. The key factors which affect the effective area calibration accuracy are extracted, and the influence path and impact on the calibration of all the various factors are analyzed. Eventually the two calibration methods accuracy is evaluated and the ways for improving the calibration accuracy are given. The effective area calibration is able to test and verify the collecting ability of X-ray photons and further more assesses the detecting performance of the grazing incidence optical system, which is the basis for the development of grazing incidence mirrors. After the effective area of grazing incidence optical system is calibrated, compared to its geometrical optical area, the roughness of grazing incidence lens can be obtained and thus the grazing incidence X-ray optical lens roughness is available.

9241-77, Session PS

structure design and optimization of an x-ray pulsar navigation instrument

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Pulsar is a kind of neutron star with rapid self-rotation. The signal it radiates has stable and precise period, which is the most remarkable property. As a new promising autonomous navigation technology, X-ray based pulsar navigation can offer position, velocity, and accurate time navigation information for the spacecraft in near-earth orbit, geostationary orbit, elliptic orbit or interplanetary orbit. Therefore, X-ray pulsar navigation has gained more attentions in current satellite autonomous navigation involving astronomy, geosciences and spatial science with an extremely important military use and wide application prospect.

The successful implementation of pulsar autonomous navigation depends on an x ray pulsar navigation instrument (XPNI), which collects and records the X ray photons emitted from pulsar precisely. The design of XPNI is a typical multidisciplinary design optimization problem, composing of optical, structure and thermal disciplines. The first design objective of XPNI is the optical performance that can be realized by the grazing incidence optics. The second design objective is to minimize the overall weight of XPNI. Actually, the working environment of XPNI is serious, which comprises the severe shock and vibration during the launching of rocket and the alternating hot and cold working environment in deep space. Therefore, how to guarantee the overall performance of XPNI while with lightest weight has become a pivotal issue.

In this paper, the working environment of XPNI was researched from the structure force, thermal deformation and background noises. Meanwhile, the related design requirements of XPNI were firstly analyzed according to the weight, effective area, detecting efficiency. Then, the preliminary design procedures of XPNI were presented in detail. After that, the optimization model of XPNI which includes two optimization objects (overall weight and effective area) is formulated, while considering the structural constraints, thermal constraints, optical constraints, performance constraints and constraints of background restraining efficiency. Secondly, with the design parameters

and variables of detector diameter, field of view, focal length, grazing angle, length and diameter of optics, the influence law of which exerted on the XPNI were analyzed. An influence matrix of the optimization model was obtained. Furthermore, the vibration degree of overall performance caused by the uncertainties of each design parameters and variables were deeply researched. After that, an advanced mathematical optimization algorithm was adopted to resolve the design and optimization of XPNI considering all the constraints. A global optimal solution was obtained, which actually it is a trade-off solution between the overall weight and effective area while meeting all the constraints and design requirements. Finally, the preliminary design structure of XPNI was implemented according to the optimal solution. Then, the model analysis, static structure analysis, random vibration, response spectrum, harmonic response and steady-state thermal analysis of optimized XPNI were implemented respectively. The simulation results showed that the design and optimization were rational and effective, which can provides theory guidance for practical engineering design.

9241-78, Session PS

A relay imaging probe to check focus map of Earth-observing pushbroom imager

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Bar chart patterns projects by collimator was adopted to measure contrast transfer function (CTF)values at Nyquist frequency before assembly of imaging sensor with telescope for earth-observing pushbroom imager. A relay imaging probe consisting of optical objective and 2D imaging sensor was builded to image these projected pattern and estimate the image quality of optical system before alignment of linear imaging sensor. By riding on a hexapod stage and measuring at a series focus position at several field angles, this probe provides a reference map for alignment of imaging sensor and image quality assessment. Certainly, testing result can be used to anticipate result of focusing alignment.

SETUP

Telescope under test is mounted on a gimbal providing horizontal rotation and tilt adjustment. Collimator is equipped with 18 testing charts with an effective focal length at about three times of that for telescope. Collimator was aligned to telescope by a theodolite. Relay imaging probe was mounted on a hexapod stage laying on gimbal. Field point shift was carried out by gimbal rotation and tilt. Measuring spectral band was defined by filters on collimator. Objectives used in this relay system have lateral magnification 10 or 20. Imaging sensor used is a monochromatic interline ccd imaging sensor with pixel pitch 9.9 ?m in both directions.

BAR CHART

Testing chart used in this test were barchart with spatial frequency at 50 lp/mm horizontally and vertically at telescope focal plane. Profiles of image captured by this relay probe was extracted and its maximum and minimum values were used to get CTF measured values by where Bdark is a dark value captured in uniform dark image.

The correction of measured value for this system.

For 50 lp/mm, frequency of imaging sensor goes to 1/20 or 1/10, and should be 2.5 or 5 lp/mm, correction factor induced by optical objectives is close to one, and can be neglected.

Results of bar chart test were compared to those derived by slanted edge, slits, and pinhole.

9241-80, Session PS

Theory, methods and principles of structural design of microwave radiometer multireceiver systems for aerospace remote sensing of land and ocean surface

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Nowadays one of the main tasks in modern unmanned exploration of space is remote sensing of the Earth and oceans. The studies forecast climate change, predict natural or man-made disasters, etc. Modern radars in aircrafts and spacecrafts currently represent one of the most rapidly growing segments of the electronic equipment. An international standards organization “The International Bureau of Weights and Measures” pays great attention to microwave radiometer due to special interest in remote sensing.

The further study of environment implies the investigation of subtle effects and complex conditions, which require higher sensitivity and reliability of radiometric equipment. The known methods of radiometric measurements, such as compensation, modulation, correlation, balance, null methods, which are used in receiving system with one or two receivers in order to increase sensitivity, worked themselves out. Increased sensitivity of radiometers based on these methods is mainly due to technological approaches and improvement of the parameters of microwave components.

One of the ways to develop a sensitive microwave radiometric system with high reliability is a method for constructing radiometers based on many (three or more) receivers, when antenna signal is measured by the same receivers in one spectral range. In this work, the development of the model of multireceiver system is based on the patented modification of the null method of measurements, which uses two types of synchronous pulse modulations - amplitude and width, thus allowing to create radiometric systems with stable parameters.

This project studies the fundamental principles and methods of development of multireceiver radiometric systems of new types, based on null method with three or more receivers and signal conversion algorithms, development of the mathematical apparatus of the fluctuation sensitivity assessment, operational reliability for applications aboard aerospace complexes.

In the publication we try to examine the possibility to develop the receiving system of the highest sensitivity on a single substrate in a single technological cycle. The system should exceed the sensitivity of ideal radiometer based on a compensation method without cryogenic cooling of the amplifier stages. This fact is of great importance in the development of the concept of microwave radiometric studies of various natural environments by remote sensing methods.

9241-56, Session 12

A study of development trends and characteristics in military surveillance/ reconnaissance and commercial satellites

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Satellites are used for a large number of purposes. Common types include military and civilian earth observation satellites, communications satellites, navigation satellites, weather satellites, astronomical space science satellites, and research satellites. Surveillance and Reconnaissance military satellite systems are required a high-resolution imaging information of the sensor acquisition performance and compact and lightweight to maximize operational capability. Military imaging satellite developed in the United States and Russia, who runs In recent years, several countries, such as Europe, Israel, Japan,

India, China, and actively seeks to develop commercial imaging satellites, several countries to participate the competition and cooperation relationships signed I'm going, and improve the performance level of the military satellite. This paper, we look at the operation and development plans are military electro-optical cameras, Surveillance and Reconnaissance satellites worldwide trends GSD 0.5m-class commercial satellite technology, satellite SiC material applied electro-optical camera and a small satellite, and satellite groups were investigated.

9241-57, Session 12

Short-wave infrared (SWIR) spectral imager based on Fabry-Perot interferometer for remote sensing

Rami Mannila, Christer Holmlund, Harri J. Ojanen, Antti Näsilä, Heikki Saari, VTT Technical Research Ctr. of Finland (Finland)

VTT Technical Research Centre of Finland is developing a spectral imager for short-wave infrared (SWIR) wavelength range. The spectral imager is based on a tunable Fabry-Pérot interferometer (FPI) accompanied by a commercial InGaAs Camera. The FPI consists of two dielectric coated mirrors separated by a tunable air gap. Tuning of the air gap tunes also transmitted wavelength and therefore FPI acts as a tunable band bass filter. The FPI is piezo-actuated and it uses three piezo-actuators in a closed capacitive feedback loop for air gap tuning. The dielectric coated mirrors have limited operation range. Therefore spectral imager contains two FPI in a stack, to make possible to cover spectral range of 1000 – 1700 nm. The spectral resolution of the imager will be in the order of 10 nm (FWHM). Field of view (FOV) across the flight direction is 30 deg. Imaging resolution of the spectral imager is 256 x 320 pixels. The focal length of the optics is 12 mm and F-number is 3.2. This imager will be tested in summer 2014 in unmanned aerial vehicles (UAV) and therefore a size and a mass of the imager are critical. In test campaign the spectral imager will be used for forest and agricultural imaging. In future, if results of the UAV test flights are promising, this technology can be applied to satellite applications also.

9241-58, Session 12

HyperCube: enabling hyperspectral imaging from nanosatellites

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A miniaturized hyperspectral instrument working in the VNIR spectral range is being developed by a European consortium led by cosine | measurement systems. The instrument will have unprecedented low mass and low power consumption and will achieve a performance to reliably accomplish the tasks of hyperspectral imaging and early warnings providing situational awareness. The signal-to-noise ratio, the spectral resolution, the ground sampling distance, and the spectral bandwidth are sufficient for early warning of many events, e.g. flooding, forest fires, landslides, stress on vegetation. Furthermore, any other variation of the soil spectral signature, as for example illegal dumps, can also be detected. The instrument has minimal impact on the spacecraft thanks to its low engineering budgets, and therefore suitable for anomalies and change detection for early warning from nano-platforms, such as CubeSats.

One of the important issues related to hyperspectral instrumentation is related to data volume. In general, current satellite earth observation systems can acquire vast amounts of data, so the bottleneck of the technology is often the limitation in downlink capacity. To overcome the downlink capacity constraint the image processing, which is traditionally executed on large data centers, will be executed onboard within the limited resource available and with a reduced set of metadata which is typically used in on-ground processing approaches.

To enable optical sensing applications on nano platforms it is critical that the systems are as light as possible, can achieve space-grade optical performance, and have been manufactured in a reliable and cost efficient manner. In general, these requirements are typically challenging each other, and novel technology development is required to push boundaries and create a new state-of-the-art within hyperspectral imaging. New technologies and materials enabling this, and currently under development, are single point diamond turning and RSA aluminum. These lead to the ability to provide telescope optics fitting the cubic decimetre size ranges.

This project is supported by ESA (GSTP Program), the Netherlands Space Office, the Norwegian Space Centre and the Belgian Science Policy Office.

9241-59, Session 12

Decoupling spatial and spectral resolutions in dispersive hyperspectral imagers

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Designing dispersive hyperspectral imaging systems requires carefully balancing spatial and spectral resolution, as well as system throughput. Inside the actual spectrometer the input slit image is dispersed and reimaged onto a detector focal plane, with the reimaged slit shape being a key factor in the system performance parameters. Tornado Spectral Systems (TSS) has developed High Throughput Virtual Slit (HTVS) technology that allows spectrometer designers to shift etendue between orthogonal axes working in pupil space, enabling the designer to change the ratio between reimaged slit width and height while maintaining the beam size and f-ratio. This allows for increased spectral resolution with the same slit width, increased detector field of view and more. With appropriate design, this etendue shifting can improve the performance or size of a dispersive hyperspectral imager by a factor of several over conventional spectrometer designs.

In its most basic form, HTVS technology uses a small number of mirrors operating in pupil space to compress the hyperspectral slit image in one axis while stretching it in the orthogonal axis. This can be used to make a slit image taller along the cross-dispersion axis and thinner along the dispersion axis (improves spectral resolution, decreases cross-track field of view [FOV] in detector limited regime) or to conversely make the slit image shorter along the cross-dispersion axis and wider along the dispersion axis (degrades spectral resolution, increases cross-track FOV in detector limited regime) without throwing out light or changing the total etendue of the system. By matching the slit image characteristics to downstream components, factors of several improvements in etendue utilization can be achieved.

TSS has implemented HTVS technology into a prototype hyperspectral imaging system. Simulation and testing show that these improvements can be achieved while maintaining spatial information.

9241-60, Session 12

Emissivity spectra estimated with the MaxEnTES algorithm

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Temperature and Emissivity Separation (TES) applied to multispectral or hyperspectral Thermal Infrared (TIR) images of the Earth provides relevant parameters for climatological studies, meteorology, and soil characterization, and is an issue relevant to many remote sensing applications. Multiband TIR radiance can be modeled by means of the well-known Planck's law, which relates the emitted radiance to the target temperature T and emissivity.

As shown in several previous papers discussing this topic, the retrieval of both temperature and emissivity is a problem admitting infinite solutions, and various approaches have been proposed for working out this problem. The main weakness of such estimators was the presence of a-priori assumptions conditioning the estimation phase. The presence of such external information or constraint was the key for removing the estimation indetermination, but it was also the main critical point. In fact, it is impossible to find a constraint or a mathematical property obeyed by the emissivity spectrum of any material, causing these algorithms to give rise to systematic estimation errors affecting the retrieved temperature and emissivity.

After the pioneering work of Shannon on the information theory, a large effort has been devoted to develop a new statistical inference approach based on the maximization of the information entropy. This new scheme for statistical inference includes methods that can be useful for fitting and inverse modeling, even in cases in which the number of unknowns exceeds the number of measurements. These procedures were mainly developed by Jaynes, and took the collective name of Maximum Entropy formalism (MaxEnt). Due to its mathematical structure, the MaxEnt approach seems to be well suited for carrying out the complex TES operation. The main advantage of the MaxEnt statistical inference is the absence of any external hypothesis, which is instead the main critical point characterizing each TES algorithm.

In this paper we describe the performance of the MaxEnTES (Maximum Entropy Temperature Emissivity Separation) algorithm as applied to the ten TIR spectral channels of a MIVIS dataset collected over Italy. We compare the emissivity spectra (images) estimated by this algorithm with independent estimations achieved with independent TES approaches (mainly the GBE and the MEC algorithms). We show that MaxEnTES is the algorithm of choice in terms of its higher output Signal-to-Noise Ratio and the negligibility of systematic errors that bias the estimated temperature [emissivity] in other TES procedures.

9241-61, Session 12

Implementation of a hyperspectral image simulation tool and performance analysis of the impact of instrumental noise on vegetation fluorescence retrieval algorithms using the telluric O2-A and O2-B lines

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A hyperspectral image simulation tool - featuring also a specific fluorescence package – has been implemented to produce image datasets of fluorescent and non fluorescent targets acquired by a generic spaceborne hyperspectral instrument. The implemented simulation tool takes into account all major effects characterising each acquisition, such as: illumination and acquisition geometry, spatial and spectral variability of the simulated scenes, the interaction of the electromagnetic radiation with the soil and the atmospheric constituents as well as the main effects introduced by the simulated instrument (e.g. foreoptic MTF, detector sampling, noise).

The simulation tool was used to create a set of hyperspectral images featuring a sub-nanometric spectral resolution and containing different types of vegetation targets. The fluorescence package has been implemented for 5 classes of vegetation, chosen amongst those most representative as for occurrence and parameters variation.

The tool was used to investigate some critical issues concerning Solar Induced Fluorescence (SIF) retrieval in vegetated areas by means of the FLD (Fraunhofer Line Discriminator) method. The latter relies in the detection of the infilling of the Fraunhofer lines of solar irradiance, due to the contribution of a fluorescent target, in order to measure the SIF emitted by the target. The radiance inside these lines is considerably lower than the offline radiance and thus it is easier to decouple the weak fluorescence signal from the measured radiance. This method has been proposed and used for vegetation remote sensing at global scale from satellite by exploiting the telluric O2-A and O2-B bands that are due to atmospheric molecular oxygen. These are in fact placed respectively at 760 nm and 687 nm, close to the maxima of the fluorescence bands of chlorophyll a fluorescence in the red spectral region. The FLD method is also at the basis of the measurement principle exploited by the FLEX/FLORIS mission of the European Space Agency, which is currently under development (phase A/B1).

In this paper we analyse the main artifacts introduced by the non uniformity of the instrumental characteristics in the simulated image dataset, taking into particular account its impact in the spectral region of the telluric O2-A and O2-B lines that can be exploited for the retrieval of the vegetation SIF. In particular, here we present the analysis of the striping disturbance as well as the spectral and radiometric calibration uncertainties. Actually, non homogeneous physical characteristics of the detector, their variations after launch or a faulty calibration are all factors that can considerably affect the performances of a push-broom imaging spectrometers as those envisaged for the FLEX/FLORIS mission.

9241-62, Session 13

Collaboration pathways via new tools for operational global climate monitoring from space

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Consistently collecting the earth's climate signatures remains a priority for world governments and international scientific organizations. Architecting a solution requires transforming scientific missions into an optimized robust 'operational' constellation that addresses the needs of decision makers, scientific investigators and global users for trusted data.

The application of new tools offers paths forward for global architecture collaboration. Recent (2014) rule-based decision engine runs optimizing the intended NPOESS architecture, becomes a surrogate for a global operational climate monitoring architecture(s). This rule-based systems tool delivers valuable insights for Global climate architectures, through the valuations of alternatives considered and the exhaustive range of trade space explored. A even more complex optimization of Global ECV (essential climate variables) monitoring architecture(s) is described in some detail with best thoughts on appropriate rule-based valuations.

Graphic representation(s) suggest/support collaborative paths forward and elicit responses from the audience & climate science shareholders.

9241-63, Session 13

Knowledge-intensive global optimization of Earth observing system architectures: a weather-centric case study

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Knowledge-intensive global optimization of Earth observing system architectures: a weather-centric case study

Requirements from the different disciplines of the Earth sciences on satellite missions have become considerably more stringent in the past decade, pushed by numerical weather prediction, climate monitoring, and societal applications among others. Hyperspectral imaging, spatial resolutions of tens of meters or better, and temporal resolutions of hours are now common requirements in Earth observing systems. At the same time, budgets in space organizations such as NASA or ESA have not increased to support the implementation of these new requirements. Moreover, several critical missions were severely descoped or delayed (NPOESS, GPM), or even lost at launch (OCO, Glory).

All this is happening at a time of rapid changes in the space arena. New technologies such as optical communications, electrical propulsion, nanosatellite technology, and new commercial agents and models (e.g. hosted payloads) are now available. These factors enable the study of radically new architectures using dense constellations of small satellites, formation-flying clusters, synthetic aperture instruments, hosted payloads, and low-cost launch opportunities.

The situation is thus ideal to reconsider the current architectural paradigm of Earth Observing Systems. The current architecture is based on relatively large multi-instrument platforms that are procured, owned, and operated by single organizations, largely independently from other assets. These architectures are currently unable to meet requirements, and are too risky and expensive. Can we satisfy more scientific and societal requirements and/or reduce cost, schedule, and risk by adopting more distributed and heterogeneous architectures that make the most of latest technological advancements?

We approach this question in a rigorous way using the latest tradespace exploration technology that mixes multi-agent systems, heuristic optimization, knowledge-based agents, and machine learning. In particular, we use a knowledge-intensive model that we developed to simulate several figures of merit for Earth observing system architectures including scientific and societal performance and lifecycle cost. While this model does not have the fidelity of Observing System Simulation Experiments, it allows the screening of thousands of different architectures with modulable fidelity.

The core of the evaluation model contains several hundreds or thousands of chunks of knowledge (e.g. rules) that encode knowledge about different disciplines of the Earth sciences and satellite engineering. For example, there are rules that estimate the characteristics (spatial resolution, temporal resolution, accuracy) of the data products obtained by a certain instrument at a certain orbit. Other agents simulate the application of different data processing algorithms to existing data products (e.g., spatial or temporal averaging, spatial disaggregation)

Furthermore, an explanation facility keeps track of all the important points of the simulation, and is capable of reasoning to answer questions such as: Why does this architecture score so high or so low? How does this architecture satisfy this particular requirement?

This paper describes the latest version of the toolset and illustrates it with a case study based on weather-centric architectures. The study considers candidate instruments from the former NPOESS program as well as new instruments such as hyperspectral millimeter-wave atmospheric sounders.

9241-64, Session 13

Simulation testbeds for the assessment of space-based wind measuring systems

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Global measurement of tropospheric wind has been widely recognized as potentially the most significant contribution of satellite remote sensing to Numerical Weather Prediction (NWP). Most of the world's oceans are largely devoid of accurate wind measurements, a deficiency that can best be addressed from space. The deployment of a space-based wind sensing instrument such as a Doppler Wind Lidar (DWL) would provide the capability to address many key issues such as hydrologic and biogeochemical cycles, planetary scale dynamics, and atmospheric-oceanic heat transport. Equally important, it would provide critical wind information for improved operational weather forecasting, and for safe, efficient, and effective military and commercial aviation operations.

Ground-based and airborne-based lidars have demonstrated the ability to make direct measurements of winds based on determination of the wind-induced Doppler shift in the backscatter signal. However, space-based application of DWL technology is without heritage. Thus, optimal design of future DWL systems for space deployment must rely upon computer model studies. These model studies include efforts with DWL performance models, atmospheric circulation models and atmospheric optical property models.

Once a candidate for a space-based wind sensing concept is chosen, an impact study is conducted to evaluate the system's global performance. When a concept has proven to warrant a larger study, a full Observing System Simulation Experiment (OSSE) is conducted and evaluated. Recently, testbed simulations were performed to support Observing System Simulation Experiments (OSSEs) evaluating several spaced-based wind sensing technology concepts.

Over the past twenty five years, Simpson Weather Associates has been funded by NASA, NOAA and DOD to develop and maintain space-based simulation models for Doppler wind lidars (DWL), differential absorption lidar (DIAL) and scatterometers; in addition, the simulation of cloud motion wind vectors. These models use Nature Runs (NR) for plausible atmospheric model field inputs. Currently, for Earth testbed simulations, either global (ECMWF T511) or mesoscale (AOML WRF) atmospheric fields are used. For Mars testbed simulations, Martian Global Climate Model (GCM) databases developed by Laboratoire de Météorologie Dynamique du CNRS, France is used.

One of the largest challenges using NR model atmosphere fields in testbed simulations is the generation of needed variables that the NR does not provide. Simpson Weather Associates' unique Atmospheric Generator Model (AGM) is coupled with NR atmospheric model fields to provide satellite's view of opaque clouds, cirrus clouds, cloud optical properties, aerosol/molecular optical properties and atmospheric turbulence information that must be considered. This paper discusses the benefits and challenges of using today's model atmospheres in simulation models to assess future space-based wind measuring systems.

9241-65, Session 13

Towards a spaceborne white-light Lidar instrument based on femtosecond filamentation

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Femtosecond laser filamentation, resulting from the nonlinear propagation of intense ultra-short laser pulses in the atmosphere, has become a promising tool for the remote optical sensing of pollutants using lidar technology. In this technique, femtosecond laser pulses in the terawatt optical power range propagate in the atmosphere behaving as quasi-solitons thanks to a dynamic competition between the optical Kerr effect focusing the beam and the induced plasma effect defocusing the beam. This results in the formation of thin plasma filaments where efficient nonlinear phenomena take place, including self-phase modulation leading to the generation of a coherent broadband continuum spanning from 300 nm to 14 ?m.

This supercontinuum generated by the filamentation process could become an attractive tool for future space-borne lidar

missions. It could allow measuring additional data about water vapour and temperature profiles, enabling the direct measurement of relative humidity in the atmosphere. In addition multispectral lidar information can be simultaneously obtained using a single laser source, thus reducing the overall complexity of the space system.

In this work, femtosecond laser filamentation initiated from orbital altitudes is investigated. The nonlinear propagation of femtosecond laser pulses launched from orbital altitude (~400 km) is characterised based on state-of-the-art numerical models. The impact of initial laser parameters (such as beam shape, laser wavelength, and initial chirp) on the filament formation is studied with the aim of gaining insights on the technical feasibility of this advanced lidar concept. Finally a preliminary description of the space system design is provided.

9241-66, Session 13

Image processing technologies for the Russian space satellite CANOPUS-V Nr.1

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Since July 2012 the Russian small space vehicle (SV) "Canopus" Nr.1 successfully carries out the terrain survey from a height of 510 km with a swath of 920 km. The SV's hardware consists of multispectral (MSS) and panchromatic (PHS) survey systems.

MSS and PHS CCD matrices are installed in the focal plane with overlapping swaths. The matrices form so-called micro-frames sized 1920x985 pixels having a radiometric resolution of 8 bits. The MSS hardware has 4 matrices, one matrix per each subband. The formed by the MSS camera images have a spatial resolution of about 10.5 km and width of about 20.2 km.

The multifunctional software NormSatB is used for on-ground processing of incoming SV's information. The developed software provides the successive execution of the following technological operations (image processing stages):

1. Primary processing of telemetry data stream registered by the antenna hardware;

2. Cataloguing of the earth surface images;

3. Forming of output information products in accordance with international standards.

At the stage of the primary processing, the registered by the antenna hardware video data stream from MSS and PHS cameras is being unpacked. There are the next procedures during this operation: micro-frame structure restoration; detection and filtration of failed rows and impulse noise; navigation measure processing; classification of micro-frames by camera types, radiometric correction and geo-coding of micro frames using parameters of inside and outside orientation of the survey systems.

Radiometric distortions of micro-frames are caused by some properties of CCD. These distortions are appeared as both changes of brightness across a micro-frame and differences in brightness of neighboring micro-frames. An algorithmic brightness distortion compensation is performed by the equation , where are the input and corrected brightness values of a pixel numbered , k is the number of micro-frame.

The corrective function is based on the mathematical model taking into consideration the physical nature of brightness heterogeneity and the survey of homogeneous regions of the earth surface. Values of mutual brightness distortions do not exceed 1-2% after the suggested radiometric correction.

Besides, the tasks to be solved during the cataloguing of survey routs are considered. The main attention is paid to cloud object selection algorithms. It is suggested the new algorithm for automatic recognition of cloud types using frames from the MSS. The algorithm is based on the stereo effect appeared during cloud object survey in different spectral subbands. The cloud objects are shifted relatively to each other onto the fused image that allows separating clouds from objects on the earth surface. The high performance of the algorithm is achieved by pre-allocating all «candidates» standing for clouds using the color characteristic.

The paper shows the estimators of errors of geo-referencing before and after geometrical calibration. It is shown that the errors of geometric micro-frame stitching come to 0.15÷0.5 pixel while the residual level of mutual brightness distortions for the overlapped micro-frames does not exceed 2 %. There are some examples of micro-frame geometrical stitching and radiometric correction, Pan-Sharpening by usage of MSS and PHS data.

The paper describes the types of output information products distributed to consumers, the image formats and metadata.

9241-67, Session 14

COSMO-SkyMed Second Generation planner

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COSMO-SkyMed Second Generation (CSG) system has been conceived, according to the requirements stated by Italian Space Agency (ASI) and Italian Ministry of Defence (It-MoD), at the twofold need of ensuring operational continuity to the current "first generation" constellation (COSMO-SkyMed - CSK), while achieving a generational step ahead in terms of functionality and performances. It is an "end-to-end" Italian Earth Observation Dual-Use (Civilian and Defence) Space System, with Synthetic Aperture Radar (SAR) operating in X-Band, for global environmental monitoring, scientific and commercial purposes and strategic applications. Due to the CSK dual use nature, partners with very different needs share the system resources that can be classified as satellite's energy resources; on-board memory resources; ground segment resources. The purpose of CSG mission is to fully employ the system resources producing a mission plan, generated by the Mission Planning Center, that satisfies the requests with higher priority and optimizes the overall plan with the remaining requests according to the users programming rights consumption. This paper intends to delineate the key elements of CSG Mission Planning tool that provides significant steps ahead in terms of adaptability and flexibility performances of the algorithms conceived to solve the planning and scheduling Operational Research (OR). This OR consists in selecting and synchronizing the acquisition and downloading activities related to image user requests considering a large number of technical and managerial constraints. CSG planning and scheduling problem is a Constraint Satisfaction Problem (CSP) characterized by a large size of research space and a particular structure of its constraints. This feature together with the experience acquired in the realization of the CSK planning and the lesson learned coming from almost seven years of operations has led to the implementation of innovative design of the planning algorithms based on both priority criteria and the saturation of system resources in the frame of CSG mission, further complicated, with respect to CSK mission, by the increasing number of requests to be processed and by the addition of new acquisition modes. This new approach envisages two scheduling strategies: the rank-based and the optimization-based. The former strategy is firstly applied to the most important Acquisition Requests categories, that are also classified as Privileged Priority (PP) and Routine (RTN) of 1÷4 class; the latter is subsequently applied to the lower priority Routine (class 5) Acquisition Requests that are processed as unranked requests. In particular, the rank-based scheduling strategy establishes that the Data Take Opportunities (DTO, i.e. the elementary items of the CSG scheduling problem)

have to be scheduled exclusively on the basis of their relative priority level expressed by the rank value assigned to each DTO according to the importance/priority given to the request submitted by the User, taking into account the whole set of system constraints. This is an iterative dynamic process that converges to optimal solutions able to better answer the demanding requirements coming from the needs of heterogeneous users providing the capability to support with an high level of service also the international partnership and cooperation implemented by ASI and It-MoD.

9241-68, Session 14

The OPTIMA project: data simulation and correction procedures for PRISMA mission products

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The OPTIMA project ("Advanced methods for the analysis, integration and optimization of PRISMA mission level 1 and 2 products") is one of the five independent scientific research funded by the Italian Space Agency to study the applications and performance of the hyperspectral sensor and panchromatic camera of the PRISMA mission. The main goal of the project is optimizing PRISMA mission level 1 and 2 products and improving mission applications for monitoring some environmental process and disaster through the estimation of surface humidity and the analysis of burned area.

One of the main tasks of the OPTIMA project is the implementation of advanced methods for radiometric calibration and atmospheric corrections to retrieve at-ground spectral reflectance maps.

In this paper we describe and discuss the optimized destriping algorithm for improved radiometric corrections implemented for the PRISMA mission and the autonomous and iterative procedure developed for the removal of the atmospheric effects from hyperspectral images. This procedure is based on a better and more accurate estimation of diffuse light contribution to the total at ground solar irradiance. It takes into account both adjacency and trapping effects, providing refined at-ground spectral reflectance images.

In addition, a sensor data simulator has been developed for testing implemented algorithms and procedure. Starting from cartographic data and spectral libraries of observed targets, the simulator calculates the at-sensor spectral radiance taking into account the principal sensor characteristics, such as IFOV and spectrometer line spread function.

Results coming from the application of the correction procedures on simulated images or Hyperion datasets are presented and discussed.

9241-69, Session 14

Pre- and post-launch end-to-end test simulation for dynamic response prediction of global Earth's albedo monitoring instrument

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In this report, we present end-to-end test simulation for dynamic response prediction of a global Earth's albedo monitoring instrument. The sensor is to observe the Sun and the Earth, alternately, and measure their shortwave radiations around L1 halo orbit. It consists of two channels that energy channel is a broadband scanning radiometer and the visible channel is an imager with 4 degree full field-of-view. The ratio of reflected to direct solar radiations can be obtained from the energy channel instrument output signals with its response across the field-of-view. For this calibration process, the instrument response needs to be characterized in pre- and post-launch. The end-to-end test simulation was conducted with opto- and electro-thermal modules. In the opto-thermal module, ray sets created from light sources were directed toward the instrument Sun- and Earth-viewing ports. And the ray sets arriving at the port were saved according to its conditions such as wavelength, incident angle, or number of rays. After selecting appropriate ray sets by test procedures, they were traced toward the energy and visible channel detectors via instrument optical elements at the same time. During scan period, incident light paths across the field-of-view were determined by scanned images obtained from the visible channel detector. In the case of the energy channel detector, temperature changes of radiation sensitive element were estimated with absorbed flux distribution and the pyroelectric material characteristics. In the electro-thermal module, charges on the electrodes and signal voltage were computed with the temperature change within the pyroelectric material. In the case of the pre-launch test simulation, a shortwave reference source assembly was used as a light source in a laboratory environment. The source assembly consists of quarts tungsten halogen lamps, 4 inch integrating sphere, neutral density filters, band pass filters and folding mirrors. All the optical parts were aligned to make a distant extended light source and optical characteristics were used as measured quantities. On the other hand, the Sun was used as a natural light source during the transfer from the Earth's parking orbit to the L1 halo orbit for post-launch test simulation. The Sun model was constructed as a real scale having solar flux obtained from Gueymard's terrestrial irradiance data. The instrument model consists of the dual channel opto-mechanical structure including the Sun- and Earth-viewing ports with measured optical properties. As a result of the end-to-end test simulation, the instrument dynamic responses were computed and pre- and post-launch predictions were compared. The simulation technique produced from this process can be used data reduction and in-flight calibration. The technical details of the simulation are presented together with the instrument development status.

9241-70, Session 14

Design and test of a near-infrared tunable liquid crystal birefringent filter

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A near infrared tunable liquid crystal birefringent filter is developed by cascading a series of optical elements including the wide range wire-grid polarizers, the nematic liquid crystal retarders and the quartz retarders. The center wavelength of the filter's bandpass could be randomly selected or scanned in the designed spectral range with almost exactly the same out-of-band suppression by harmoniously adjusting the driving signals. The tuning range of the filter is 900nm~1700m,the clear aperture is over 50mm, the bandpass FWHM is about 15nm @900nm.The filter provides more flexible functions such as random wavelength selection and arbitrary spectral scanning step. Due to the excellent imaging quality and the relatively wide angle-of-acceptance with a large aperture, the filter enable snapshot spectral imaging sensors and compact systems without any moving parts , which is of great use in a wide variety of applications such as remote sensing

for environmental monitoring, agriculture census, mineral resources detection

9241-71, Session 14

A framework for multisource and multiscale remote sensing data normalization processing system

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More and more satellites and remote sensing sensors are operating and more and more Earth Observing (EO) information are subsequently provided for research and operational departments. Beginning with CHARTER, the tendency of using the EO information from different platforms and sensors for satisfying comprehensive EO is more and more obvious, which is strengthened with the concept of Virtual Constellation proposed by CEOS. However, all these work are limited to requirement analysis, data management, and regional data collecting, but they have not stepped into theoretical researches on virtual constellation data construction and the method for data applications. In this study, we proposed a framework for spatially, radiometrically, and spectrally normalizing remotely sensed data from different platforms and sensors with different spatial resolutions; a remote sensing dataset from multi-source with highly consistency on geometry, radiation, and spectra is consequently produced, which will serve for information digging and comprehensive applications from multi-level, multi-scale and multi-source remote sensing data. In this framework, with the analysis of characterization of current platforms and sensors, the processing system for two scales, 30m using Landsat/TM as base and 1km using EOS/MODIS as base, are constructed. The processing system for each scale includes method set on geometric registration based on image-image matching, cross calibration, Top-of-Atmosphere (TOA) and Bottom-of-Atmosphere (BOA) spectrum matching, and atmospheric correction. In addition, the method for data reading, writing, resampling, and gridding are also integrated in this framework.

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9242-1, Session 1

Cloud pattern prediction from geostationary meteorological satellite images for solar energy forecasting

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Intraday photovoltaic (PV) electricity production forecasting is crucial for a massive and safe integration of this energy into the grid. This meteorological parameter obviously depends on cloudiness, a stochastic parameter difficult to predict within the next hours with weather models. Solar irradiance forecasts have been implemented using images from meteorological geostationary satellites with better results than meteorological modeling. They consist in assessing cloud motion over an area of interest and predicting cloud pattern evolutions by extrapolation of the current one. Then, the combination between predicted cloud structure and a clear sky model provides the mapping of the predicted solar irradiance.

Cloud motion vector (CMV) extraction is a wide research field of image-processing. However, only techniques were tested for solar energy forecasting purposes. We propose to test CMV fields retrieved from different techniques in order to forecast surface solar radiation from Meteosat-10 images. Accuracy of CMV extraction techniques is then assessed by comparing solar irradiance forecast with those measured with pyranometers.

Among techniques used on CMV extraction from meteorological geostationary satellites, most of them are based on the estimation of the optical-flow. Such estimation methods produce 2D dense motion vector fields. They have been developed since the 1980's, initially for the reconstruction of the motion of solid objects from a pair of images. Today, we can classified them into three mathematical features: the correlation, the partial differential equations and the data assimilation.

The correlation-based method assumes that cloud shape has the same structure in consecutive images, such methods search similar pattern in both image. Image blocks from the different images presenting a maximal correlation are assumed to contain the same cloud structure. The vector between the successive positions of the block is then determined.

The second method uses partial differential equations for the determination of the motion. The minimization of a cost function for the optical flow constraint equation enables the determination of the motion vector field. This equation is based on the conservation of intensity and neighborhood constraints.

Finally, optical flow calculation method based on data assimilation techniques is applied on a series of images. The motion vector field is determined when the difference between an "observed" motion vector field (constructed in a first place by an optical flow method) and a predicted motion vector field (calculated from previous fields with equations of dynamics) is minimized.

We used a seasonal representative 4-month (January, April, July and October 2013) dataset of day-time Meteosat-10 images. We converted them into cloud index maps using Heliosat-2 method. Three different CMV techniques were used to derive three different CMV fields datasets over Western Europe. These latter were used to extrapolate a given image to six hours ahead or less if sunset occurred before. Comparisons between forecast results were made using six BSRN stations located in Europe.

In terms of forecast accuracy and by averaging the performance of the six stations, the three methods shows similar results close to the state-of-the-art. However, the computation time of correlation based methods is definitively the shortest in any case.

9242-2, Session 1

Active remote sensing observations for cirrus clouds profiling at subtropical and polar latitudes

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The influence of cirrus clouds on weather and climate is actually an evident fact. Indeed, they can act as modulators in the radiation balance of the Earth-atmosphere system, and their heating or cooling effects can be observed at both regional and global scales (Liou, 1986). However, the reaction of cirrus clouds to factors resulting from human-induced climate changes (i.e, greenhouse effect and contamination of the upper troposphere from increasing aircraft traffic) is still poorly investigated. The climate-related changes in cirrus cloud properties could alter (i.e., enhancing, opposing or even negating) the widely assumed global warming effect related to the aerosols. In particular, in a changing climate, cirrus induced by aircraft contrails would increase the upper tropospheric albedo and counteract the greenhouse gases warming effect. The predominance of infrared greenhouse warming versus solar albedo cooling depends sensitively on both the altitudes and microphysical compositions of the cirrus clouds. Indeed, cloud height has an evident impact. Hence, high tropical cirrus (i.e., formed from deep convection above warm moist layers) can be particularly effective greenhouse modulators. Conversely, lower cirrus over polar regions could be more efficient for albedo effects. Thus, mid-latitude cirrus clouds are assumed to reveal radiative implications varying with the season. Moreover, cirrus clouds are product of weather processes, and then their occurrence and macrophysical/optical properties can vary significantly over different regions of the world.

In this sense, a few case studies of cirrus clouds observed at both subtropical and polar latitudes are presented in this work. Observations are carried out in three stations: Sao Paulo (SP, Brazil, 23.6°S 46.8°W) managed by the Instituto de Pesquisas Energéticas e Nucleares (IPEN), and Sta. Cruz de Tenerife (SC, Spain, 28.5°N 16.3°W) by the Agencia Estatal de Meteorología (AEMET), being both subtropical sites, and the Belgrano II base (BE, Argentina, 78ºS 35ºW), by the Dirección Nacional del Antártico (DNA), in the Antarctic continent. Active remote sensing (LIDAR) is used for profiling measurements and cirrus clouds features are retrieved by using a recently proposed methodology (Larroza et al., 2013). Specific instrumental features related to that applied retrieval algorithm (range-corrected signal vs. backscattering ratio, optimal threshold function, among others) for each lidar system used in this work are examined. Case studies are selected in dependence on the season and altitude where cirrus clouds are found. Radiosounding profiles are also used in this analysis for cirrus temperature estimation. Optical and macrophysical properties (COD-cloud optical depth, top/base heights, thickness and Lidar Ratio-extinction-to-backscatter ratio, mainly) of both the subtropical and polar cirrus clouds are reported. Similarities/discrepancies found between them and radiative forcing implications are also discussed.

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9242-3, Session 1

Fast rendering of clouds from 3D radiative transfer computations

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The availability of very high spatial resolution sensors has for the past few years allowed a precise description of atmospheric scenes for remote sensing and surveillance applications. Clouds presence in the field of view is one of the key factors limiting the performances of these sensors for target detections. However, in order to develop such detection algorithms for images with a fine spatial resolution, a fast 3D radiative transfer tool dedicated to scene generation is necessary to obtain large number of realistic cloud scenes. Three dimensional effects become more important when going to higher model resolution. For that purpose, fast solutions are needed since three-dimensional radiative transfer solvers are computationally far too expensive.

Two different strategies are presented in this paper. On the one hand, an optimization of the explicit method Spherical Harmonic Discrete Ordinate Method (SHDOM) developed by Evans, K. F. (1998), associated with a fast image rendering solution. On the other hand, fast approximations of 3D radiative transfer.

SHDOM takes advantage of spherical harmonic angular representation to compute and store source functions together with discrete ordinates description to achieve accurate computations of radiance fields. This method is well suited for producing images since source functions are precomputed first and then radiances can be computed along any lines of sight defined by a field of view. The optimization is based on Graphics Processing Unit (GPU) computing allowing an acceleration of time calculation while ensuring physical accuracy.

Concerning approximations of 3D radiative transfer, several of them have been developed for surface solar irradiances or fluxes in climate models. For radiances in various viewing conditions, we have developed new approaches using computationally inexpensive one dimensional radiative transfer solvers and Tilted Independent Column Approximation (TICA) for geometrical effects. This paper gives a brief description of each method for visible to infrared radiances. These new parameterizations of 3D image radiances are then applied to realistic microphysical cloud scene and the results are compared with the optimized SHDOM code.

9242-4, Session 1

Retrieval of area-averaged and spectrally resolved surface albedo from transmission data alone: computationally simple and fast approach

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Surface albedo is a key parameter for studies of the Earth's radiation balance and satellite/airborne remote sensing of aerosol and clouds. Despite impressive progress in retrieving the surface albedo from the atmosphere and space, there is a critical need for improved estimates of the albedo, especially under cloudy conditions. The improved retrievals – when considered from an operational perspective -- should be simple and require only a few inputs. Here we present a simple retrieval of area-averaged surface albedo using ground-based measurements of atmospheric transmission alone at five wavelengths (415, 500, 615, 673 and 870nm), under fully overcast conditions. Our retrieval is based on a one-line semi-analytical equation and widely accepted assumptions regarding the weak spectral dependence of cloud optical properties, such as cloud optical depth and asymmetry parameter, in the visible and near-infrared spectral range. To evaluate the performance of our retrieval, we use as input measurements of spectrally resolved atmospheric transmission from Multi-Filter Rotating Shadowband Radiometer (MFRSR). These MFRSR data are collected at two well-established continental sites in the United States supported by the U.S. Department of Energy's (DOE's) Atmospheric Radiation Measurement (ARM) Program and National Oceanic and Atmospheric Administration (NOAA). The area-averaged albedos obtained from the MFRSR are compared with collocated and coincident tower-based point measurements of the local surface albedo. In particular, these comparisons are made at five wavelengths and for four seasons (winter, spring, summer and fall) at the ARM site using multi-year MFRSR and tower-based data. We find good agreement, on average, for appropriate cases with relatively uniform surface properties. Additionally, we demonstrate: (1) how the point measurements can be used to improve the estimation of area-averaged surface albedo for cases with inhomogeneous surfaces; and (2) how well albedos retrieved under fully overcast conditions represent albedos for clear and partly cloudy days.

9242-5, Session 1

Connecting ground-based in situ observations, ground-based remote sensing and satellite data within the Pan Eurasian Experiment (PEEX) program *(Invited Paper)*

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Human activities put an increasing stress on the Earth' environment and push the safe and sustainable boundaries of the vulnerable eco-system. It is of utmost importance to gauge with a comprehensive research program the current status of the environment, particularly in the most vulnerable locations. Pan-Eurasian Experiment (PEEX) is a new multidisciplinary research program aiming at resolving the major uncertainties in the Earth system science and global sustainability questions in the Arctic and boreal Pan-Eurasian regions.

The PEEX program aims to (i) understand the Earth system

and the influence of environmental and societal changes in both pristine and industrialized Pan-Eurasian environments, (ii) establish and sustain long-term, continuous and comprehensive ground-based airborne and seaborne research infrastructures, and utilize satellite data and multi-scale model frameworks filling the gaps of the in-situ observational network, (iii) contribute to regional climate scenarios in the northern Pan-Eurasia and determine the relevant factors and interactions influencing human and societal wellbeing (iv) promote the dissemination of PEEX scientific results and strategies in scientific and stake-holder communities and policy making, (v) educate the next generation of multidisciplinary global change experts and scientists, and (vi) increase the public awareness of climate change impacts in the Pan-Eurasian region.

The development of PEEX research infrastructure will be one of the first activities of PEEX. PEEX will find synergies with the major European land-atmosphere observation infrastructures such as ICOS a research infrastructure to decipher the greenhouse gas balance of Europe and adjacent regions, ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network-project), and ANAEE (The experimentation in terrestrial ecosystem research) networks and with the flag ship stations like the SMEARs (Station for Measuring Ecosystem-Atmosphere Relations) when designing, re-organizing and networking existing station networks in the Northern Pan-Eurasian region.

In the PEEX domain it is important to connect the comprehensive ground-based data to satellite observations in order to understand the overall context and relevance of the ground based observations. The satellite observations provide information on regional to global scales with spatial resolution varying from meters to tens of km, depending on the instrument and technique used. Likewise, spatial coverage and repeat time depend on the swath width and orbit. Of particular interest in the context of PEEX are land, lake and atmospheric observations. The atmospheric observations are complementary to those from the stations described above in that they provide information on atmospheric concentrations of aerosols, trace gases and GHG.

In this contribution, we underline general features of the satellite observations relevant to PEEX research program and how satellite observations connect to the ground based observations.

9242-6, Session 1

Managing uncertainty in cloud and precipitation property retrievals with multiple synergistic remote sensors *(Invited Paper)*

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The principal motivation for the suite of remote sensors now operating at the ARM fixed and mobile sites is to document processes related to the production of clouds and precipitation in atmospheric columns. This process-related motivation is based on the recognition that the formation and maintenance of clouds and precipitation must be understood and represented accurately in atmospheric models. The fact that the AR5 generation of models continues to be challenged to accurately represent the earth's hydrological cycle underscores the importance and relevance of the ARM objective. In this paper we seek to explore the capacity for millimeter-wavelength Doppler radar, lidar, microwave radiometer and other ancillary ARM measurements to simultaneously resolve the properties of clouds, precipitation and atmospheric vertical air motions. Using traditional optimal estimation methodology as well as more sophisticated statistical approaches such as Markov Chain Monte Carlo techniques, we will illustrate the strengths and weaknesses of this multi sensor approach using sensitivity studies and case studies with measurements.

9242-7, Session 1

Influence of broken cloud fields on reflectance retrievals

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This paper will discuss the influence of broken cloud fields on the retrieval of surface reflectance from spectral data collected by aircraft or space-based sensors. Spectral remote sensing is a valuable means of identifying surface targets and materials via their inherent, unique spectral signatures. Currently, reflectance retrieval codes are optimized for uniform atmospheric and surface illumination conditions, which is not the case when clouds are present. Under partially cloudy conditions there are two main cloud-induced effects: shadows which results in diminished ground illumination, and illumination enhancement of sunlit areas due to the photons scattered from the clouds into these areas. The work presented here will focus on the sunlit areas, leaving the reflectance retrieval from shadowed areas for a future paper.

In the reflective domain (visible to the SWIR), the application of atmospheric compensation algorithms to sunlit areas in the vicinity of broken clouds leads to inaccuracies because of the enhanced number of photons scattered from the clouds into these areas. These illumination effects are investigated in this work by simulating a variety of simple geometric clouds shapes, such as cloud slabs, spheres, and checkerboard patterns, as well as more complex broken cloud fields, using the MCScene simulation package. MCScene is a high fidelity model for full optical spectrum (UV through LWIR) hyperspectral image simulation. MCScene provides an accurate, robust, and efficient means to generate spectral scenes for algorithm validation, sensor design studies, and investigation of radiation transport phenomenology. MCScene utilizes a Direct Simulation Monte Carlo approach for modeling 3D atmospheric radiative transfer, including full treatment of molecular absorption and Rayleigh scattering, aerosol absorption and scattering, and multiple scattering and adjacency effects, as well as scattering from spatially inhomogeneous surfaces. The model includes treatment of land and ocean surfaces, 3D terrain, and 3D surface objects. Cloud fields of arbitrary shape and density can be added to the simulation by providing a three-dimensional array of cubic cloud voxels. Cloud optical properties are based on the standard MODTRAN cloud types, which include cumulus, altostratus, stratus, stratus/stratocumulus, nimbostratus, standard cirrus, sub-visual cirrus, and fog.

The cloud illumination enhancement effects on surface reflectance retrieval are examined for a hyperspectral scene with an optically opaque slab-cloud placed at the top of the scene and vertical stripes of material reflectance used for the flat terrain. The retrieved reflectance values are compared to truth reflectance as a function of distance from the cloud. The cloud scattered photons change both the magnitude and shape of the retrieved reflectance values up to four km away from the cloud. Also presented are simulations of the illuminated clouds looking up from ground toward the cloud bottoms to assess the importance of cloud geometry on illumination enhancement.

9242-8, Session 1

Multi-platform in-situ and remote sensing techniques to derive Saharan dust properties during AMISOC-TNF 2013

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The vertical distribution of dust plays a significant role regarding atmospheric radiative forcing issues (IPCC, 2013). In addition, height-resolved information of the dust properties is also required for both aerosol forecast modeling and satellite data validation. Canary Islands offer a suitable site as located downwind of the Saharan sources for dust monitoring. The arrival of dust plumes to that area is a regular feature, more frequently observed in summertime and extended up to high altitudes. The vertical characterization of individual dust events is relevant for the determination of the so-called Saharan Air Layer (SAL), defined as a mass of warm and dusty air, in order to evaluate the climate impact of such phenomena, even at local scales.

AMISOC-Tenerife (AMISOC-TNF) was planned as a multi-instrumented campaign carried out from 01 July 2013 to 05 August 2013 (36 days) over Tenerife area to study the behavior of minor traces gases under clean skies and heavy aerosol loading and the dust impact in climate-related studies. Indeed, among all AMISOC activities, a particular emphasis was focused on dust profiling characterization. Hence, simultaneous aerosol vertical observations were carried out by using different platforms and techniques: airborne in-situ measurements (PCASP and CAPS aerosol sondes aboard INTA aircraft C-212) together with ground-based remote sensing instrumentation (aerosol NASA/MPLNET lidar and NDACC/MAX-DOAS spectrometer), besides NASA/AERONET sun-photometer columnar-integrated data were also used. Backtrajectories of air masses and meteorological analysis complete this study.

First results obtained for SAL characterization during AMISOC-TNF campaign are presented in this work. Dusty conditions were reported during 50% of the overall campaign period (18 out of 36 days) as defined by AERONET Aerosol Optical Depth (AOD) and Angstrom Exponent (AEx) values, respectively, higher than 0.2 and lower than 0.5. Saharan origin was identified by HYSPLIT backtrajectory analysis. Two flights were performed under high dust loading, reporting the dust size distribution (SD) for both the particle accumulation and coarse modes (PCAPS: 0.1-3 micrometers, and CAPS: 0.5-50 micrometers). Extinction coefficient profiles and Lidar ratio (extinction-to-backscatter ratio, LR) values were obtained by using MPL lidar measurements. Attempts of aerosol profile inversion by using MAX-DOAS O4 signature retrievals were also performed.

This study reflects the synergy of multi-platform in-situ and remote sensing techniques to derive both the optical and microphysical properties of the Saharan dust layer. Among those properties are considered vertical aspects (single/multi-layered structure, SAL top height, among others) of the dusty episodes, as well as other dust features (Free-Troposphere dust contribution to the total AOD, LR frequency, particle SD mode predominance, mainly).

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9242-9, Session 2

Combining satellite optical remote sensing and radiative transfer simulation of spherical and non-spherical atmospheric aerosols to increase the performances of downstream applications in the fields of renewable energy and healthcare

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We present an innovative method for the remote near real-time monitoring of spectral solar irradiance at ground based both on satellite optical remote sensing and on the optical characterization of spherical and non-spherical aerosols particles. In particular the method has been successfully integrated in the frame of two existing downstream services respectively in the fields of renewable energy and UV dosimetry, with an overall increase of their performances and reliability.

The method is based on the synergetic exploitation of the libRadtran Radiative Transfer Model (RTM), a modified version of the Heliosat-2 algorithm and a novel method for characterizing nano- and micro-particles with spherical and non-spherical shapes. Indeed we use the RTM to calculate the radiative transfer of solar radiation into the atmosphere in almost cloudy-free conditions taking into account the simulated optical properties of aerosols. This allows the simulation both of the radiation arriving at ground but also of the radiation back-scattered into the satellite sensor in different visible and infrared bands. By means of this approach we are able to monitor in near real-time the effects of aerosols on the radiative transfer into the atmosphere in almost clear-sky conditions.

Then we further exploit this first result in the frame of a modified version of Heliosat-2 algorithm, that consists in the exploitation of the MSG visible channels to calculate a degree of cloudiness in near real-time with high spatial resolution (1 Km) and to combine this information with a reference clear-sky spectral Global Horizontal Irradiance (GHI) in order to monitor the actual GHI incident at ground in near real-time in different spectral bands.

Given that the global accuracy of this method for GHI satellite remote sensing in near real-time depends on the accuracy of the clear-sky GHI estimate, our new method greatly benefit from the inclusion of the results obtained from the combination of radiative transfer modelling and aerosols optical properties simulation described before.

The first validation tests of this new method, performed by comparison with ground measured spectral radiation data, showed good results with an overall increase of accuracy with respect to previous satellite-based methodologies.

This method has been successfully applied inside two different downstream applications, the first one dedicated to solar energy plants performance monitoring and the second one to remote UV dosimetry.

The solar energy application consists in the exploitation of the near real-time GHI obtained thanks to our new method and to calculate the irradiance actually incident on each solar receiver of the solar plant. Then using an opto-electronic model of each part of the plant, we can calculate the daily behavior of the alternate current power yield. This value of energy could be compared every day with the measured one to readily detect eventual malfunctions and to evaluate the performances of the plant.

In the UV case instead the GHI is calculated only in the UV part of the spectrum and is exploited to provide a near real-time calculation of the UV index that is combined with the Minimum Effective Dose of each person in order to provide a personal remote UV dosimeter and avoid skin damages or sunburn.

9242-10, Session 2

Experimental work of aerosol retrieval for SGLI on board GCOM-C1

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The second generation global imager (SGLI) will be mounted on global change observing mission - climate satellite (GCOM-C1) planned to be launched in winter of 2017. The SGLI will measure intensity of the reflected solar light from near UV to thermal infrared at nadir angle and its polarization characteristics at selected channels with large tilting angle (+45 or -45 degrees along track direction) in order to enhance the polarization signal. The information on linear polarization can be available for efficient estimation of aerosol optical thickness. Because the polarized signal from the Earth surface is usually weak and spectrally almost invariant. On the other hand, polarization information plays an important role for derivation of particle characteristics in light scattering process. That's why polarization measurements are extremely useful to retrieve atmospheric aerosol properties.

Another unique feature of the SGLI is measurements of total intensity at a wavelength of 0.38 μm, which is a heritage of the previous Japanese imager ADEOS-2/GLI and CAI (Cloud Aerosol Imager) on GOSAT. It has been shown that the spectral information at near UV wavelengths is very useful for retrieving aerosol properties especially for carbonaceous particle.

This work proposes algorithms involving vector radiation simulation for aerosol retrieval of GCOM-C1/SGLI and presents the obtained optical properties of aerosols based on the combination use of MODIS or GOSAT/CAI and POLDER.

9242-11, Session 2

Estimation of optical aerosol properties and bidirectional reflectance from PARASOL/POLDER data over land

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When monitoring target areas covered with vegetation in a global scale, it is very useful to estimate the vegetation index using the surface anisotropic reflectance, which is dependent on both solar and viewing geometries, from satellite data. The PARASOL/POLDER observes the reflectance and polarization of a target quasi-simultaneously in multi-viewing angles at wavelengths of 490nm, 670nm and 865nm and so POLDER data provide enough information to estimate optical properties of aerosols and the surface reflectance. In this study, the algorithm for estimating optical parameters of Atmospheric aerosols such as the optical thickness (?), the refractive index (Nr), the mean radius of small particles in two modal log-normal size distribution functions (a) and the bidirectional reflectance (R) from only the radiance and polarization at the 865nm channel received by the PARASOL/POLDER is described.

Another parameters of size distribution: standard deviation, ?s, of the small particle, mean radius, rg, and standard deviation, ?g, of the large particle were fixed, and those values were estimated from monthly averaged size distribution at the AERONET site managed by NASA near the target area. Ground-based polarization measurements of light ray reflected by the grassland were also made, using the multi-spectral polarimeter, PSR1000, developed by Opt Research Corporation, Japan. As a result, it was found that degrees of polarization of the reflected light by the grassland are very low values at the 865nm channel. This indicates that the contribution of the surface reflectance to the polarized radiance received by the satellite is small. Aerosol properties such as ?, Nr and a in an atmosphere were estimated, by comparing only polarized radiances received by the POLDER with those computed by the radiative transfer code (6sV-1.0B code). Since aerosol properties in the atmosphere were determined, the bidirectional reflectance can be easily derived from the total radiance received the POLDER. In this study, the bidirectional reflectance given by the Ross-Li BRDF model was used. This BRDF model is defined as a sum of three terms, isotropic scattering term (fiso), volume-scattering term (fvolKvol(?,?,?)) and geometric-optical term (fgeoKgeo(?,?,?)), where Kvol is the RossThick kernel and Kgeo is the LiSparse kernel, and ? is solar zenith angle, ? is viewing zenith angle and ? is relative azimuth angle. We first used the 6SV-1.0B code to compute total radiances at the top of atmosphere for typical values of Lambertian reflectance (fiso) under geometric conditions given in POLDER data and then determined inversely the value of fiso from the measured radiances by means of the least square method. In this case, values of fvol and fgeo were assumed to be zero. After that, the estimated value of fiso was fixed and values of fvol and fgeo were estimated from total radiances received by the POLDER.

The estimation algorithm developed in this study was applied to PARASOL/POLDER data over the Japanese islands taken on April 28, 2012. The estimated optical thickness of aerosols was checked with those given in the AERONET and fvol and fgeo of the estimated BRDF were compared with those of vegetation measured from the radio-controlled helicopter. Consequently, it is shown that this algorithm provides reasonable values for aerosol properties and surface bidirectional reflectances.

9242-12, Session 3

Spectral reference line data relevant to remote sensing applications: a review and outline of the EUMETRISPEC project

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Speckle noise which is inherent to Synthetic Aperture Radar (SAR) imaging obstructs various image exploitation tasks such as edge detection, segmentation, change detection, and target recognition. Therefore, speckle reduction is generally used as a first step which has to smooth out homogeneous regions while preserving edges and point scatterers. Traditional speckle reduction methods are fast and their memory consumption is insignificant. However, they are either good at smoothing homogeneous regions or preserving edges and point scatterers. State of the art despeckling methods are proposed to overcome this trade-off. However, they introduce another trade-off between denoising quality and resource consumption thereby higher denoising quality requires higher computational load and/or memory consumption. In this paper, a local pixel-based total variation (TV) approach is proposed which combines l2-norm and l1-norm in order to improve despeckling quality while keeping execution times reasonably short. Pixel-based approach allows efficient computation model with relatively low memory consumption. Their parallel implementations are also more efficient comparing to global TV approaches which generally requires numerical solution of sparse linear systems. However, pixel-based approaches trapped to local minima frequently hence despeckling quality is worse comparing to global TV approaches. Proposed method, namely mixed norm despeckling (MND), combines l2-norm and l1-norm in order to improve despeckling performance by alleviating local minima problem. All steps of the MND are parallelized using OpenMP on CPU and CUDA on GPU. Speckle reduction performance, execution time and memory consumption of the proposed method are shown using synthetic images and TerraSAR-X spot mode SAR images.

9242-13, Session 3

Variability of Mediterranean aerosol properties at three regional background sites in the Western Mediterranean Basin

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In the framework of the project ChArMEx (the Chemistry-Aerosol Mediterranean Experiment, http://charmex.lsce.ipsl.fr/), the variability of aerosol optical, microphysical and radiative properties is examined in three regional background sites on a southwest – northeast (SW – NE) straight line in the middle of the western Mediterranean Basin (WMB). The three sites are on the northward transport pathway of African dust:

• Alboran, Alboran Island, Spain (35.94ºN, 3.04ºW, 15 m a.s.l),

• Palma de Mallorca, Mallorca Island, Spain (39.55ºN, 2.62ºE, 10 m a.s.l) and

• Ersa, Corsica Island, France (43.00ºN, 9.36ºW, 80 m a.s.l).

AERONET (AErosol RObotic NETwork) sun-photometer products are mainly used. A preliminary analysis shows that at Ersa and Palma sites the annual aerosol optical thickness (AOT) has a similar trend with a peak around 0.2 in July. The winter/spring AOT is lower in Palma than in Ersa, while it is reverse in summer/autumn. The size distribution (and the coarse mode fraction) shows clearly the SW – NE gradient with a decreasing coarse mode peak (and a decreasing coarse mode fraction from 0.5 - 0.35 - 0.2 in July) along the axis Alboran - Palma de Mallorca - Ersa.

In addition to the seasonal and annual variability analysis, the analysis of AERONET products is completed with a large variety of ground-based and sounding balloons remote sensing and in situ instruments during two Special Observation Periods (SOP) in summer time, the TRAQA and ADRIMED campaigns in June-July 2012 and June 2013, respectively. The second part of the presentation will focus on the comparison of the observations at Palma de Mallorca and Ersa of the same long-range transported airmasses. The observations include lidar vertical profiles, balloon borne OPC (Optical Particle Counter), MSG/SEVIRI AOT and CALIOP profiles, among others.

9242-15, Session 3

Retrieval of boundary layer height from lidar using extended Kalman filter approach, classic methods, and backtrajectory cluster analysis

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Planetary boundary layer (PBL) height is an important input in numerical applications such as weather and air quality modelling as it delineates the top of the atmospheric mixing layer. Lidars (laser radars) with high spatial (< 30 m) and temporal resolutions (< 5 min) can be employed to monitor the PBL height using backscattered aerosols as tracers. This contribution evaluates an approach using an extended Kalman filter (EKF) to estimate the PBL height from a multiwavelength Raman elastic-backscatter lidar in different synoptic flows over the complex geographical area of Barcelona, Spain (41.389 N, 2.112 E, 115 m ASL).

PBL heights diagnosed with the adaptive EKF technique are qualitatively compared with three classic methods to estimate PBL height from lidar used in previous studies. All lidar-based methods are then validated against PBL heights derived from radiosoundings using a bulk Richardson number approach. Regular lidar measurements obtained in the framework of the European Aerosol Research LIdar NETwork (EARLINET) at 12 UTC ± 30-min. for a 7-year period, 2007-2013, are categorized under different synoptic flows. A total of 46 30-min. or 1-hr. lidar time-height series have been selected.

The synoptic situations are identified using a cluster analysis technique of HYSPLIT (HYbrid Single Particle Lagrangian Integrated Trajectory) kinematic backtrajectories computed once per day at 12 UTC for a 16-year period: 1998-2013. A total of 5756 individual backtrajectories are input to the cluster analysis algorithm. Three-day backtrajectories arriving at 500 m, 1500 m, and 3000 m above mean sea level, represent the lower PBL, upper PBL, and low free troposphere, respectively. Seven clusters are determined at each arriving altitude and compare similar to previous works. Regional recirculations from the east or west are clearly dominant and account for 54% of the annual total at 500 m and 57% of the total lidar measurement days at 1500 m, with a clear preference for summertime (500 m: 36% and 1500 m: 29%).

PBL height retrievals at 12 UTC using the EKF method range between 790 m and 1.6 km ASL with cases in the 1500 m synoptic clusters. Highest PBL heights are observed in SW flows (15.2% of total lidar days) and regional recirculations from the east (34.8% of total lidar days), mainly caused by the stagnant synoptic pattern in summertime over the Iberian Peninsula. The lowest PBL heights are associated with N (19.6% of total lidar days) and NE (4.3% of total lidar days) synoptic flow patterns, where new air masses tend to lower the boundary layer.

The adaptive feature of the EKF technique allows the retrieval of reliable PBL heights without the need for long time averaging or range smoothing, as typical with many of the classic methods. It is shown that with proper initial state vector estimates the EKF method performs superior to other methods in estimating the PBL height.

9242-16, Session 3

Analysis of aerosol transport patterns from Northern Europe into the Arctic in spring 2013 using Raman Lidar data

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In spring 2013 the first ANNA campaign took place in Northern Europe and the Arctic. Five measurement stations, located in the European sub-Arctic and Arctic regions are equipped with Raman lidars: Kuopio and Sodankylä in Finland, Andenes in Norway as well as the Polish Polar Station in Hornsund and the German Koldewey station in Ny-Ålesund on Svalbard. They measured from 1st of February until 31st of May 2013 with a covering rate of 25% in Hornsund and up to 97% in Kuopio. Other data like sun photometer, ceilometer and other elastic lidars are available as well. In winter/spring 2013 (January to May), the probed air masses were mostly of Arctic origin, due

to mostly Arctic transport. The match case identification was done with HYSPLIT trajectories. Out of 480 runs (4 times daily) with four altitude trajectories from five different stations, e.g. 9600 trajectories, a little less than 1000 of these trajectories result in red warnings, e.g. pass another station in 100 km distance (50 km for Hornsund and Ny-Ålesund). The northward transport has been limited within this winter, 78% of the red warning trajectories were associated with southward transport. Only less than 5% of the red trajectories from the mainland reached Svalbard. Several aerosol layers have been detected above Kuopio in 2013, mainly in March and April, mostly they are of Arctic origin.

One case study is presented as an example for a case of Arctic origin. An aerosol double layer structure at 4 to 6 km altitude has been observed for 9 hours on the 9th of March. With wind speeds of 43 km/h it had almost 400 km extent. The inversion algorithm gives the following results: The layers particles have an effective radius of 0.17 nm. The higher layer consists of larger particles with a higher imaginary and a lower real index. The layers are of Nordic origin, coming from Kamtschatka in early March, where there has been volcanic activity reported.

9242-17, Session 3

Retrieving the microphysical characteristics of cirrus clouds from lidar data by depolarization and color ratios

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Cirrus clouds consisting of ice crystals cover about 30% of Earth's surface. They have a great impact on the radiative budget and climate. Therefore their accurate radiative and microphysical properties are needed to incorporate into up-to-date general circulation models of the atmosphere. Usually these properties are parameterized from the experimental data obtained for the solar and thermal infrared radiation. Various algorithms have been developed to retrieve cirrus optical and microphysical properties in the past twenty years. In this parameterization, as known, there is a problem to take into account the spatial inhomogeneities of cirrus clouds that correspond to inhomogeneities of both concentration and microphysics (size, shape and orientation) of the ice crystals. Lidars are more sensitive tools for measurements of the above-mentioned inhomogeneities of cirrus clouds. Here the backscattering coefficient while retrieved as a vertical profile is the product of the number concentration and backscattering cross-sections of the crystals at the given altitude. It is obvious that it is only the backscattering cross-section that is responsible for the microphysics (size, shape and orientation of the ice crystals). However any procedures of retrieving the microphysical characteristics from the lidar data are not developed yet because of a lack of the theoretical solution for this problem.

In this study, the desired solution has been obtained by means of the beam-splitting algorithm developed by the authors within the physical optics approximation. This approximation allows us to solve the problem of light backscattering by ice crystals of cirrus clouds most efficiently. The solution for the randomly and quasi-horizontally oriented ice crystals is obtained as a data bank. Here the numerical data includes the cases of crystal sizes from 10 to up 1000 microns and two wavelengths of 0.532 and 1.064 microns. As follows from these data, the randomly oriented crystals reveal a relatively large magnitude of the depolarization ratio of about 0.2 - 0.5 depending on both sizes and aspect ratios of the crystals as well as a detector field of view. The quasi-horizontally oriented crystals, on the contrary, have small depolarization ratios less than 0.1. Thus, the magnitude of the depolarization ratio distinguishes between the random and quasi-horizontal crystal orientations. The depolarization ratio proves also to be a perspective tool for assessments of the microphysical structure of the clouds because of its independence of particle concentration. We have calculated the depolarization ratios in the vicinity of the backward scattering direction for both the randomly oriented crystals and quasi-horizontally oriented crystal plates.

It is worthwhile to note that the depolarization ratio for the randomly oriented hexagonal columns has a gap of the angular width lambda/D, where lambda is the wavelength and D is the diameter of the hexagon facets, that could be a base to create algorithms for retrieving microphysical cloud parameters. As for the quasi-horizontally oriented crystals, the color ratio looks more informative. We show that it essentially depends on flutter of the quasi-horizontally oriented crystals and, consequently, can be used to retrieve the effective angle of the flutter.

9242-18, Session 3

Monitoring particulate matters in urban areas in Malaysia using remote sensing and ground-based measurements

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Monitoring particulate matter less than 10 ?m (PM10) near the ground routinely is critical for Malaysia for emergency management because Malaysia receives considerable amount of pollutants from both local and trans-boundary sources. Nevertheless, air pollutants data covering major cities over a large spatial extent and on a continuous manner are limited in this region. In recent years, satellite remote sensing has provided the ability to retrieve aerosol properties over large areas in a continuous manner.Thus, in the present study we aimed to estimate PM10 at 1 km spatial scale using AOD derived from MERIS satellite at 3 metropolitan cities in Malaysia. MERIS level 2 AOD data covering 2 years (2007-2008) were combined with PM10 data measured at 11 locations in Peninsular Malaysia covering Klang valley (west coast), Penang (northern state) and Johor Bahru (southern region) metropolitan cities. PM 10 data measured at hourly intervals were provided by the Department of Environment Malaysia. This study is different from previous studies conducted in Malaysia because in the current study we estimated PM10 by considering atmospheric stability, surface temperature and relative humidity derived and/or calculated from MODIS data and digital elevation model obtained from SRTM (shuttle Radar Topography Mission) satellite data and our product will be at ~1 km spatial scale. Results of this study show that MERIS AOD recorded highest value (between 0.6-0.9) during the dry season (September-October) and lowest values (0.3-0.4) in the monsoon season (December-January). The direct correlation between monthly averaged AOD and PM10 (corresponded to the time of satellite overpass) yielded a low and insignificant relationship with R2= 0.04 and RMSE = 7.06 ?g m-3. However, when AOD, relative humidity, land surface temperature and k index (atmospheric stability and thereby vertical mixing) were combined in a multiple linear regression analysis the correlation coefficient increased to 0.47 and the RMSE decreased to 6.25 ?g m-3. Among the variables k- index showed highest correlation with PM 10 (R2=0.35) compared to other variables. This shows that atmospheric stability is important for predicting PM10 because under unstable atmospheric conditions (increased boundary layer height) the vertical and horizontal mixing of aerosols increased that improves the correlation between satellite observations (column integrated aerosols) and PM 10 that is concentrated within the boundary layer. We further improved the relationship between PM10 and the independent variables using Artificial Neural Network analysis. Results show that the correlation coefficient of the calibration dataset increased to 0.58 with low RMSE of 3.72 ?g m-3. The model (predicted PM 10 values) was then validated with independent PM 10 measurements and the accuracy is satisfactory with R2= 0.74 and RMSE = 4.07?g m-3.

The results may change when we consider more data points covering 10 years (2002-2011) and enable the construction of a local model to estimate PM10 in urban areas in Malaysia.

9242-54, Session 3

An inter-comparison study between vertically resolved ceilometer data and aircraft measurements during a Sahara dust period in Germany: first results

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At the beginning of April 2014 a pronounced Sahara dust cloud propagated over large areas of Germany and Europe. The German Weather Service DWD could detect and monitor the expansion and propagation of this dust cloud with a ceilometer network of more than 50 ceilometers. Moreover, these ceilometers were also able to track the altitude of the dust cloud at the positions of the ceilometers.

Additionally, aircraft measurements over Germany and France were performed with two aircraft by the Düsseldorf University of Applied Sciences. These aircraft were equipped with optical particle counters and were able to measure the concentrations within the Sahara dust cloud as well as the particle size distributions of the dust. The ceilometer measurements and the aircraft measurements complemented each other: whereas the ceilometers gave continuous information about the Sahara dust cloud at the ceilometer positions, the aircraft measurements delivered interpolating results between the ceilometer positions. Moreover, at several ceilometer positions intercomparison flights were performed by spiraling with the aircraft up or down around the ceilometer laser beam. This gave the unique possibility for comparing the remote sensing results of the ceilometers with the in-situ measurements of the aircraft. It could be shown during this intercomparison study that the ceilometers and the aircraft measurements delivered results about the Sahara dust plume which were in good agreement. Several examples for these intercomparisons will be shown at in this conference. Further intercomparison studies like this are planned for the future.

9242-38, Session PS

Natural and anthropogenic particles over East Asia

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It is well known that the aerosol distribution in Asia is complex due to both the increasing emissions of the anthropogenic aerosols associated with economic growth and the behavior of natural dusts. Therefore, detailed observations of atmospheric particles in Asian urban cities are important. A characteristic atmospheric event over East Asia region is an Asian dust in which sand and soil particles are raised and transported by storms to make the atmosphere turbid. Major sources of the Asian dust are located in arid and semiarid regions in Asian continent. Dry surface conditions and a strong wind are necessary for causing these dust storms. Dusts have various impacts on the environment and human society. Dusts affect the radiation balance through their scattering and absorbing solar and thermal radiation as well as affecting the atmospheric composition through their chemical reaction in the air. It is also recognized that small soil particles in the air are harmful to the human respiratory system. Furthermore Asian dusts are transported with anthropogenic pollutants to downwind region. In this work, I focus on transportation of Asian dust and anthropogenic pollutant and variations in particulate matter around Japan which is located at downwind region from Asian continent. Various ground measurement devices are placed around Higashi-Osaka in Japan including a Cimel sunphotometer supported by NASA/AERONET (aerosol robotics network), suspended particulate matter (SPM) sampler and LIDAR (light detection and ranging). The SPM sampler provides particle information about the concentrations of PM2.5, PM10 and OBC separately. To investigate the change of size and composition of particulate matter, I analyse the particulate matter with a scanning electron microscope (SEM) coupled with an energy-dispersive X-ray analyser (EDX). The sampling data with the PM sampler are available. The characterization of atmospheric particles over Higashi-Osaka varies especially when Asian dust reaches to Higashi-Osaka. Nonspherical particles with large particle size are dominant during dust event. It is clear that silicon, which is possibly from soil particles, become dominant for large particles and the sulphur from anthropogenic source is dominant for small particles during dust event. The change of particle properties suggests that a certain amount of natural and anthropogenic particles are transported to Higashi-Osaka. I investigate the transportation process of both natural and anthropogenic particles using numerical model simulations.

9242-39, Session PS

A neural network approach for monitoring of volcanic SO2 and plume height using hyperspectral measurements

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In this study two neural networks were implemented in order to emulate a retrieval model and to estimate the sulphur dioxide (SO2) columnar content and cloud height from volcanic eruption. ANNs were trained using all Infrared Atmospheric Sounding Interferometer (IASI) channels in Thermal Infrared (TIR) as inputs, and the corresponding values of SO2 content and height of volcanic cloud obtained using the Oxford SO2 retrievals as target outputs.

The retrieval is demonstrated for the eruption of the Eyjafjallajökull volcano (Iceland) occurred in 2010 and to three IASI images of the Grímsvötn volcanic eruption that occurred in May 2011, in order to evaluate the networks for a different eruption.

The results of validation, both for Eyjafjallajökull and Grímsvötn independent data-sets, provided root mean square error (RMSE) values between neural network outputs and targets lower than 20 DU for SO2 total column and 200 mb for cloud height, therefore demonstrating the feasibility to estimate SO2 values using a neural network approach, and its importance in near real time monitoring activities, owing to its fast application.

Concerning the validation carried out with neural networks on images from the Grímsvötn eruption, the RMSE of the outputs remained lower than the Standard Deviation (STD) of targets, and the neural network underestimated retrieval only where target outputs showed different statistics than those used during the training phase.

9242-40, Session PS

Volcanic emissions from AIRS observations: detection methods, case study, and statistical analysis

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Volcanic aerosol particles such as ash or secondary aerosol formed from volcanic sulfur dioxide have significant impact on

radiative forcing and are an important natural cause of climate variations. Furthermore, volcanic ash can cause extensive damage to aircraft and therefore poses a severe danger to aviation safety. Satellite instruments are well suited to monitor volcanic emissions continuously and on a global scale. Satellites provide long-term records, which can help to study the climate impact of volcanic emissions. Near-real-time processing of satellite data allows to raise warnings on potentially hazardous situations for aviation.

Here we focus on the detection of volcanic emissions from hyperspectral infrared nadir observations, in particular on measurements from the Atmospheric Infrared Sounder (AIRS) onboard NASA's Aqua satellite. AIRS provides 4 to 15 micron infrared radiance spectra for 2.9 million footprints per day almost continuously since May 2002. In contrast to measurements in the visible or ultraviolet spectral region, the infrared measurements by AIRS depend on thermal emissions of the atmospheric constituents and are available at day- and nighttime. Nadir sounders also provide excellent horizontal resolution, which allows to observe the fine filamentary structures of volcanic plumes.

We discuss two fast and optimized detection methods for volcanic ash and sulfur dioxide from AIRS observations. The detection of volcanic ash is based on the well-established `reverse absorption' technique, which relies on the specific spectral characteristics of volcanic ash particles around 10.4 and 12.0 micron. Likewise, to detect sulfur dioxide we use an index method, which relies on brightness temperature differences of two AIRS channels in the 7.3 micron absorption band. We carefully selected the AIRS channels for both index methods in order to optimize the detection sensitivity.

To further characterize both detection methods, we carried out radiative transfer calculations to obtain vertical weighting functions with respect to particle concentrations and size distributions of volcanic ash and volume mixing ratios of sulfur dioxide. We also applied radiative transfer calculations to analyze correlations between the ash detection index and the aerosol optical depth as well as the sulfur dioxide detection index and the sulfur dioxide total column. We tested both detection methods in various case studies in different atmospheric conditions. We also processed the full 11-year record of AIRS observations from 2003 to 2013 and analyzed the detection results statistically. Local area median and interquartile ranges of ash and sulfur dioxide indices are used to optimize detection thresholds and to better discriminate between volcanic emissions and more regular emissions, e.g., desert dust.

The new volcanic emission data sets presented here were already applied in several recent studies of volcanic emission events. The data sets are also featured in the scientific visualization contest of the 2014 IEEE VIS conference to be held in Paris, France in November 2014.

9242-41, Session PS

Identifying volcanic endmembers in hyperspectral images using spectral unmixing

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"Spectral unmixing technique is used in remote sensed data analysis for the determination of certain basis spectra called 'endmembers'. Once those spectra are found, the image cube can be 'unmixed' into fractional abundance of each material in each pixel.

In the present work infrared spectra recorded by Infrared Atmospheric Sounding Interferometer (IASI) were used to characterize the emission from Grimsvotn volcanic eruption on 2011. In particular, a methodology based on spectral unmixing theory was used in order to extract the spectral signature of volcanic cloud constituents, such as ash and sulphur dioxide (SO2) and maps of their abundances in a IASI image were obtained.

Taking the advantage of IASI broad spectral coverage the broadband signature in the Thermal Infrared (TIR) radiance spectra in the 1000-1410 cm-1 range associated with the presence of aerosols was obtained. Volcanic ash and SO2 spectral signatures were extracted, as well as those related to the simultaneous presence of ash, SO2 and water.

The study proved that spectral unmixing, applied to Hyperspectral images, is able to identify volcanic aerosols and other species like SO2 despite a strong presence of meteorological clouds.

Moreover, the analysis of hyperspectral datasets permitted to generate abundance maps for each endmember extracted. In particular, maps obtained for the test case of 2011 May, 23th put in evidence the separation between clouds of ejected SO2 and volcanic ash. The former dispersed at Northern latitudes, whilst the latter was situated at southern latitudes, South of Iceland."

9242-42, Session PS

Air pollutant retrieval in East Asia from space and ground: Algorithm improvement

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Air pollution in East Asia has become severe in recent years, with heavy air pollutants and Asian dust being transported from China to neighboring countries throughout the year. We focus on aerosol remote sensing around Beijing, China in June when serious aerosol episodes were detected by both satellite and ground measurements. This work is aimed at developing an efficient algorithm for aerosol remote sensing around urban areas in East Asia. The atmospheric aerosol distributions in East Asia are known to be complicated, owing to both natural factors and human activity. In urban areas, small anthropogenic aerosols dominate because of emissions from diesel vehicles and industrial activity. Thee aerosol distribution in East Asia is especially known to be heavily affected by the increasing emissions of sulfuric, nitric or carbonaceous aerosols associated with continued economic growth. The increasing emissions of anthropogenic particles provide the concentrations of serious air pollutants. While extreme concentrations of aerosols in the atmosphere can prevent aerosol monitoring with surface-level sun/sky photometers, satellites can still be used in such conditions to observe the Earth's atmosphere from space. It is therefore important to retrieve precise aerosol characteristics from space. Aerosol distribution varies seasonally because of various factors such as emissions, photochemical reactions and wind direction. Furthermore, Asian dust events, which are some of the most dynamic natural phenomena to produce atmospheric aerosols, can increase particulate matter concentrations and can cause serious atmospheric turbidity. Atmospheric aerosols also influence climate because they play an important role in global environmental change and meteorology. Therefore, it is important to observe aerosol characteristics and their temporal and spatial variations from the ground and from space.

In this study we investigate the aerosol characteristics during serious aerosol episodes (dense concentrations of aerosols in the atmosphere) detected by both satellite and ground measurements. Our procedure is applied for Aqua/MODIS or GOSAT/CAI data in East Asia in June from 2007 to 2010. We conclude that air pollution over Beijing is mainly due to both the increasing emissions of the anthropogenic aerosols associated with economic growth and the complicated behavior of natural dust. However, carbonaceous aerosols from agriculture biomass burning in Southeast Asia also contribute to the pollution. Air quality is worse in big cities than in remote areas, therefore high resolution measurements of atmospheric

aerosols in spatial- and temporal- scales are needed in Asian urban cities such as Beijing.

9242-43, Session PS

Analysis of microphysical processes in fog

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Fog is a significant phenomenon in meteorology which could cause non-ignorable losses for public transportation when visibility is reduced in a large extent. In this paper, four fog events are analysed from a comprehensive fog observation campaign at the Cabauw Experimental Site for Atmospheric Research (CESAR, http://www.cesar-observatory.nl/) in the western part of the Netherlands to investigate the fog characteristics during the evolution. The development of fog is observed with the in-situ and remote sensing synergy at CESAR and a 35 GHz cloud radar in “fog mode” has been used for the first time.

Fog drop size distribution (DSD) is an important parameter for describing different fog types and lifecycle stages of fog related to spatial and temporal variations. FSSP (Forward Scattering Spectrometer Probe) installed at 60-m level of the Cabauw tower is employed to measure fog drop size distribution covering 30 size bins within the range of 3-46.5 ???? diameter. Microphysical parameterization of fog is first introduced as the basis for analysing the microphysical processes during the fog evolution. The general microphysical characteristics of the four fog events are studied and key microphysical parameters (droplet number concentration, liquid water content, mean radius, and spectral standard deviation) are found lower than those in other sites due to the low aerosol concentration at Cabauw. To study how the fog develops, the datasets are equally divided into four stages according to the variations of visibility: formation stage, mature stage I, mature stage II, and dissipation stage. Since the mature stage takes up much time of the whole period, it is further divided into two stages I and II representing the ascending and declining periods of the microphysical properties. The microphysical processes and factors that would affect fog microphysics are examined by the microphysical relationships in the lifecycle stages of fog. The positive correlations between every two of the microphysical parameters in the lifecycle indicate the dominant process is likely to be droplet activation with subsequent hygroscopic growth and droplet evaporation. The dominant processes are also supported by the different negative correlations of visibility and radar reflectivity in the lifecycle stages of fog.

However, other mechanism could exist in fog, although not dominating. Collision-coalescence is a significant factor for the continuous growth of big fog droplets when they have reached certain sizes in the mature stage. The collision-coalescence process is distinguished from the negative correlations among the microphysical parameters in the lifecycle of a stratus-fog case. It is evidenced by the large increase of radar reflectivity with almost constant visibility in the period of collision-coalescence occurred, for the radar reflectivity is more strongly affected by large droplets than the visibility.

In conclusion, the results show the dominant processes in fog is the droplet activation with subsequent hygroscopic growth and droplet evaporation, but the collision-coalescence process would counteract the effects of the dominant processes representing as the continuous growth of big fog droplets with almost constant number concentration.

9242-44, Session PS

Three-dimensional fusion of reflectivities from space and ground radar observations

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1. Introduction

The precipitation radar (PR) on the Tropical Rainfall Measuring Mission (TRMM) satellite is the first space-based weather radar, and the availability of PR is a great asset for the observation of precipitation. In the past decades, TRMM PR has successfully obtained a great number of three dimensional (3D) rain structures in tropical and subtropical zone. The advantages gained were the high vertical resolution of the PR, while it has a low sensitivity threshold of 18dBZ. The ground radar (GR) has relatively good capability to detect weak precipitation and relatively good horizontal resolution. Thus, the joint utilization of PR and GR is an important factor in maximizing the benefit to be reaped from both instruments, which also has been proposed by previous authors. In this paper, we will blend the PR data and GR reflectivity in Nanjing, China based on image fusion algorithm. The fused image will has greater sensitivity to detect precipitation, has improved 3D spatial resolution and may gain finer precipitation structure.

2. Data

A case study of the image fusion of PR and GR in China at 9 July, 2007 is performed, and the orbit number is 54960. The Nanjing radar operates at S-band, the range resolution is about 1km, and the 3dB beamwidth is about 1o. For the subsequent data fusion, the PR and GR reflectivity data should be registered in a common coordinate system. Therefore the Nanjing GR is firstly remapped to the 3D Cartesian coordinate system and a grid data is obtained with a 3D resolution about 1km×1km×1km. The PR data is selected in the scan area of 300 km×300km centered at the Nanjing GR site with a 3D grid of about 4km×4km×0.25km.

3. Processing and results

Integrating PR and GR mainly includes following steps: spatial-temporal mathup of PR and GR data, calibration bias correction of Naning GR, image fusion algorithms selection and quality evaluation of the fused image. The spatial-temporal matchup scheme is based on the method provided in the papers about the comparisons of PR and GR. Before performing image fusion, a calibration bias correction is carried out by statistics comparisons of PR and GRs in China and the detection of inconsistencies between adjacent GRs. It is found that an approximate 4dBZ bias is existed in Nanjing GR. The scatter plot and the difference between PR and GR are also presented, and the correlation coefficient is nearly 0.85. Then, the PR and GR data are resampled to the same grid of 1km×1km×0.25km with the bilinear interpolation method. The image fusion is based on the weighted average algorithm, the maximum algorithm and the linear regression algorithm. The 3km CAPPI and vertical profile are displayed with the three fusion algorithms. Finally, the quality of the image fusion is evaluated via statistics analysis of correlation coefficient, root mean square error and other parameters. With the 3D fusion of reflectivities from PR and Nanjing GR, more information like weak precipitation and finer precipitation structure can be gained. Future work will include rainfall retrieval with the fused precipitation image.

9242-47, Session PS

Estimation of cloud height and speed using ground-based stereophotography: Methods, error analysis and first results

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Retrieval errors of the atmospheric composition using optical methods (DOAS et al.) are under the determining influence of the cloudiness during the measurements. If there is information about the clouds, the optical model of the atmosphere used to interpret the measurements can be adjusted, and the retrieval error are reduced.

For the reconstruction of the parameters of the clouds was taken up a method based on taking pictures of the sky by a pair of cameras and subsequent processing of the obtained sequence of stereo of frames by a method of morphological analysis of images.

Since the directions of the optical axis of the cameras are not exactly known, the graduation of the direction of sight of the cameras was conducted at the first stage using the photographs of the stars in the night sky. As a result, the coefficients of the affine transformation relating own coordinate systems of the cameras were determined. The authors have confined themselves to affine transformations, as the angle between the optical axes was small enough, and the corresponding points on the stereo pair was chosen near the optical axis.

At the second stage, the relative shift of the image of the cloud fragment on the second frame of the pair was calculated. Stereopairs obtained by simultaneous photography, allowed us to estimate the height of cloud, and analysis of images recorded at different times, allowed to determine the speed of the clouds.

The report describes a mathematical model of measurement, pose and solve the problem of graduation of direction of sight of the cameras, describes methods of combining of image fragments by morphological method, the problem of estimating cloud height and speed of their movement is formulated and solved. The examples of first evaluations in a real photo are analyzed.

9242-49, Session PS

FY-3B microwave sensors data assimilation experiments in hybrid data assimilation system

Huang Jiang Ping, Yan Jun, Fangyou Zhang, Du HongLiang, Beijing Aviation Meteorological Institute (China)

The second satellite in new Chinese afternoon-configured polar-orbiting satellites Fengyun series(FY-3B) was launched on November 5,2010. It onboard with the four-channel Microwave Temperature Sounder(MWTS) and five-channel Microwave Humility Sounder(MWHS).In previous studies, the FY-3A MWTS and MWHS radiance data assimilation effects in WRF-3DVAR system was pointed out .

A Hybrid ensemble Kalman transform filter-variation data assimilation method(Hybrid DA) was a new assimilation method based on the variational analysis and ensemble methods .This study used a Hybrid DA method to illustrate the impact of the MWTS/MWHS in numerical weather forecast. Studies had shown that assimilation MWTS and MWHS radiance data used Hybrid DA assimilated play important role in the Typhoon forecast, The errors of the tracks and intensity forecasts by the Hybrid DA method were reducer than those by the WRF-3DVAR. Experiments showed that such improvements were due to use the “flow-dependent” ensemble background covariance and ensemble mean background.

On the other hand, evaluated the quality of the MWTS/MWHS usually by comparing radiances what measured by satellite and calculated by the radiative transfer model , it was called OBS-Modeled TB. TB is calculated by the radiative transfer model with the NWP as its input which was single NWP ‘s result, But it could bring the more errors to assesses the observation quality. This paper utilized the ensemble mean instead of the single model result as input to radiative transfer model, studies showed that used the ensemble mean to assesses the quality of the MWTS/MWHS were reasonable.

9242-50, Session PS

Cloud detection of hyperspectral imagery based on Sparse Support Vector Machine

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Remote sensing images are always influenced by atmospheric density and clouds, a large number of surface objects are obscured by different type of cloud. It is issue undoubtedly in the image interpretation tasks. So cloud detection is an important preprocess step in the remote sensing images accurately. When the surface condition is snow or ice, cloud detection is difficult because of insufficient contrast with the surface radiance.

A hyperspectral image cube contains hundreds of spectral bands with very fine spectral resolution. It’s a great advantage to distinguish the cloud from other surface. However, it also faces the problem in data transmission and storage due to vast data volume.

Many previous study can show that there is no real difficult to detect and characterize easy clouds with the methods using a few band based on physical model. However, these schemes are not very effective for clouds with small rediative effects on the observation. The above bands can’t also provide accuracy result. So the approaches based on machine learning are better ways.

For hyperspectral imaging, band selection is a very desirable preprocessing step, particularly, on pixel cloud detection tasks is need a band selection process to reduce the redundant information without losing classification accuracy in a significant way and using supervised information. Apparently, how to obtain the less effective bands is crucial factor for on-board algorithm.

So, in this paper, Sparse SVM is presented to select the effective bands which are benefit for cloud detection. Concretely, we tackle the first and last objective by proposing the use of a sparse L1 linear support vector machine (SVM), which naturally performs feature selection without recurring to specific heuristics. Contrary to standard SVMs, which minimize the L2 norm of the model weights, the proposed classifier minimizes the L1 norm, which forces most of the weights of the features to be zero and, thus, performs selection of the relevant features among a predefined set.

As a test of this technique, we have performed an experiment using EO-1 Hyperion hyperspectral data over the coast waters of Oahu, Hawaii. The approach that is presented has a stable behavior for different image data set and noticeable accuracy.

9242-51, Session PS

Absorption properties of atmospheric aerosol based on photoacoustic spectroscopy

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Atmospheric aerosol plays an important role in atmospheric radiation balance through absorbing and scattering the solar radiation, which changes local weather and global climate. Accurate measurement is highly requested to estimate the radiative effects and climate effects of atmospheric aerosol. Photoacoustic spectroscopy (PAS) technique, which observes the aerosols on their natural suspending state and is insensitive to light scattering, is commonly recognized as one of the best candidates to measure the optical absorption coefficient (OAC) of aerosols. In the present work, the high performance PA cells were designed based on the PAS theory and a photoacoustic spectrometer was established for measuring the OAC of atmospheric aerosols at the SWIR wavelength. To improve the sensitivity, a micro-hole muffler was designed to control the noise derived from vibration from sampling pump. To calibrate OAC of aerosol accurately, the NO2 gas with the known absorption efficiency was used. Using the established PAS instrument, optical absorption properties of the atmospheric aerosol at a suburban site of Hefei city were carried out. A differential absorption technique of the PAS for measuring aerosol OAC at the wavelength where could also be absorbed by vapor was proposed and corresponding measurements of the absorption properties of the atmospheric aerosol near 1.3 micrometer were carried out. And the OAC of aerosols 9.6±2.24 Mm-1 is firstly measured in the open atmosphere.

9242-53, Session PS

FY-3B microwave sensors data assimilation experiments in Hybrid DA system

Jiang Ping Huang, Jun Yan, Zhang FangYou, Du HongLiang, Beijing Aviation Meteorological Institute (China)

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9242-19, Session 4

Release 2 data products from the Ozone Mapping and Profiler Suite (OMPS) Limb Profiler

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The OMPS Limb Profiler (LP) was launched on board the NASA Suomi National Polar-orbiting Partnership (SNPP) satellite in October 2011. OMPS-LP is a limb-scattering hyperspectral sensor that provides ozone profiling capability at 1.5 km vertical resolution from cloud top to 60 km altitude. The use of three parallel slits allows global coverage in approximately four days. The initial release of OMPS-LP ozone data took place in December 2012. Since then, we have made a series of corrections and improvements to the gridded radiance (L1G) and ozone profile retrieval (L2-O3) algorithms that improve the accuracy and quality of these products for Release 2. L1G improvements include dynamic correction of wavelength registration, static and dynamic tangent height adjustments, and simplified pixel selection from multiple images. L2-O3 improvements include a revised instrument noise characterization, exclusion of channels contaminated by stratospheric OH emission, revised visible wavelengths (Chappuis bands) and reference wavelengths, a simplified aerosol correction at visible wavelengths, improved synthetic solar spectrum, implementation of pressure and temperature ancillary data from Goddard Earth Observing System Model-Version 5 (GEOS-5) outputs, and the smoothed MLS ozone climatology. Release 2 data products also include aerosol extinction profiles (L2-AER) derived with the prelaunch retrieval algorithm.

Our initial evaluation of OMPS LP Release 2 data is good. Zonal average ozone profile comparisons with Aura MLS data typically show good agreement, within 5-10% over the altitude range 20-50 km between 60 S and 60 N. Specifically, increasing the assumed instrument noise in the ozone retrieval reduces high-frequency vertical structure in the retrieved UV and visible ozone profiles, and improves ozone values in the lower mesosphere by about 5-10%. The exclusion of OH emission contaminated UV wavelengths (306.5-311 nm) improves retrieved ozone values by about 5% in the altitudes around 40 km and above 50 km. Using a high resolution solar spectrum constructed from SUSIM UV irradiance data and MODTRAN calculated visible and IR data improves the quality of the UV retrieval residuals, although the actual change in retrieved ozone is not significant. The aerosol profiles clearly detect exceptional events such as volcanic eruptions and the Chelyabinsk bolide in February 2013. OMPS LP also consistently detects polar mesospheric clouds (PMCs) in both hemispheres. We will present further results from the full LP Release 2 data set.

9242-20, Session 4

Validation of AIRS high-resolution stratospheric temperature retrievals

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Gravity waves play a major role in atmospheric physics. They transport momentum from lower to higher altitudes and have

important effects on the general circulation. Gravity waves are generally unresolved or poorly resolved in most global models. Satellite observations determine the temperature amplitudes or temperature variance associated with atmospheric gravity waves. They offer the opportunity for global studies of the characteristics of gravity waves. Limb and occultation measurements provide different advantages and disadvantages compared to nadir instruments. The main advantage is the good vertical resolution and sensitivity to gravity waves with short vertical wavelengths. A disadvantage of current limb sounders is the limited horizontal resolution and reduced sensitivity to short horizontal wavelengths. In contrast, nadir instruments are typically limited to observations of gravity waves with longer vertical wavelengths, but they provide better horizontal resolution.

This paper focuses on nadir observations made by the Atmospheric Infrared Sounder (AIRS) aboard NASA's Aqua satellite. The study is based on a nine-year record (2003-2011) of stratospheric temperatures retrieved with a high-resolution retrieval of AIRS measurements. This high-resolution retrieval provides temperature profiles for each individual footprint. The horizontal sampling of this dataset therefore is nine times higher than the operational data provided by NASA. The retrieval configuration is optimized so that the results provide a trade-off between spatial resolution and retrieval noise which is considered optimal for gravity wave analysis.

For validation of temperatures of the high-resolution retrieval the data are compared with results from the AIRS operational Level 2 data and ERA-Interim reanalysis data.

Due to the large amount of data we performed a statistical comparison of the high-resolution retrieval and reference data sets based on zonal averages and time-series. The temperature data sets are split into day and night, because the AIRS high-resolution retrieval uses different configurations for day- and night-time conditions. The temperature data are averaged on a latitudinal grid with a resolution of one degree. The zonal averages are calculated on a daily basis and show significant day-to-day variability. To further summarize the data we calculated monthly averages from the daily averaged data and also computed zonal means. Additionally, the standard deviation of the three data sets was computed.

The results show the high-resolution temperatures are in reasonable agreement with the validation data sets. The bias in the zonal averages varies between 1-2 K reaching a maximum of 4 K. The structure and value of the standard deviation is nearly the same in all three data sets having the maximum around the polar vortex. Based on these results the data are a valuable asset for further studies of gravity waves.

9242-21, Session 4

Towards an integrated infrastructure for accurate H2O remote sensing validation

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Remote sensing approaches, in particular via satellites, allow a long-range and continuous observation to provide large datasets with excellent global coverage for the investigation of key questions in climate research and mete-orology. The quality management of such retrievals depends not only on satellite parameters, but in particular on the accuracy of the underlying spectral line parameters and the validation of the satellite products, the latter is frequently done via local in-situ measurements on airborne platforms like research planes or high-flying balloons. For these two processes usually line data measurements and local in-situ sensing validations are realized uncorre-lated and by independent research groups. Combining these two processes to encompass traceable line parame-ters and local validations, however, promises better quantified uncertainties, a more rigid validation and thus the most reliable results. A typical and important example is atmospheric H2O detection: Water shows a very large spatial variability, a huge dynamic range and the simultaneous occurrence in multiple phases (ice particles, water droplets and water vapor). H2O detection thus possess a significant measurement challenge for satellites but also for airborne platforms. Additionally, H2O (in its three phases), provides the strongest total greenhouse effect and is of highest climatic relevance ranging from for atmospheric chemistry to the atmospheric radiation balance [1] [2].

To improve the accuracy of atmospheric water measurements, the Physikalisch-Technische Bundesanstalt (PTB) started to bridge interests from the metrology, the environmental physics and the meteorology community [3] by combining A) accurate spectral line data measurements (for laser hygrometers) with B) sensor developments and field tests of innovative, mobile, spectroscopic transfer standards for airborne in-situ water vapor detection, and C) with a direct linkage of A) and B) to the national primary water vapor standard. A) Is based on a unique lab-based line parameter measurement infrastructure, using FT-IR and TDLAS (tunable diode laser absorption spec-troscopy). B) is making use of a suite of traceable, calibration-free airborne TDLAS-hygrometers [4], such as SEALDH-I, SEALDH-II and HAI which were successfully employed on numerous, global flight campaigns in the lower troposphere and the upper troposphere lower stratosphere (UTLS) regions wordwide, and C) is realized by traceable validations at the national German humidity standard.

In this contribution we will present this integrated approach to remote sensing validation which combines high-accuracy line data measurement for the core of the retrieval process with reliable, transfer standard-typed air-borne measurement systems for local validations. The combination of both, aims to benefit the remote sensing community for their investigation of the global water cycle. We will present concepts and measurement results, both, on sensor validation [4] and flight campaigns to address how a strong link between meteorology and me-trology could benefit remote sensing.

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9242-22, Session 4

Influence of large and supersize droplets on propagation of Lidar radiation in cloud aerosol: numerical statistical simulation

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When constructing mathematical models of radiation

transfer in liquid-drop clouds, research is often restricted to interaction of radiation with small particles (1 - 20 μm). This interaction makes a major contribution towards attenuation and scattering of radiation in the visible range. In this paper, a numerical comparison of the influence of droplets of various size (small, large (20 - 100 μm) and supersize (100 - 1500 μm)) on the propagation of radiation in wavelength range from visible to submillimeter (100 -1000 μm) was carried out. Although the concentration of large and supersize droplets in clouds is small and they make a very small contribution to the water content of clouds, but they have a significant impact on the propagation in submillimeter range. Time distributions of ground-based LIDAR echo-signal intensity reflected off a flat layer of a liquid-drop cloud were obtained by the Monte Carlo method taking into account single and multiple scattering. We consider a polydisperse liquid-drop cloud whose optical parameters were calculated in the case of presence of large and supersize droplets as a model of the scattering medium. Distribution densities of droplet size for small, large and supersize drops and the parameters of these distributions for different types of clouds are presented in [1]. Optical parameters for the mathematical model of radiation propagation (attenuation and scattering coefficients, scattering indicatrix) were calculated according to Mie formulas using Wiskombe's algorithm [2, 3]. Values of the complex refractive index of water used in the calculation of scattering parameters are given in [4]. The non-stationary integral radiation transfer equation with stochastic kernel [5] was being solved for modeling radiation propagation. The complex boundary conditions related to the finite size of the source, radiation beam and small phase volume of the detector are responsible for typical requirements to the technique of statistical modeling and determine the necessity of using local estimates which, though labor-intensive, are the only possible method of calculating the radiation properties. The research results show that taking into account large and supersize droplets in the mathematical optical model of a scattering medium leads to significant growth of signal intensity from the cloud's lower boundary and an increase in multiple scattering background for wavelengths over 100 microns.

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9242-23, Session 5

Airborne midwave and longwave infrared hyperspectral imaging of gases

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Characterization of gas clouds are challenging situations to address due to the large and uneven distribution of these entities as a function of time. Whether gas characterization is carried out for gas leaks surveys or environmental monitoring purposes, explosives and/or toxic chemicals are often involved. In such situations, airborne measurements present distinct advantages over ground based-technics since large areas can be covered efficiently in addition to retrieving information from a safe distance. Airborne thermal hyperspectral imaging was carried out on smokestacks and a ground-based gas releases in order to illustrate the benefits of this technic to characterize gases. Quantitative airborne chemical images of carbon monoxide (CO) and ethylene (C2H4) were obtained from measurements carried out using a midwave (MWIR, 3-5 um) and a longwave (LWIR, 8-12 um) airborne infrared hyperspectral sensor respectively. Scattering effects were observed in the LWIR and MWIR experiments on smokestacks as a result of water condensation upon rapid cool down of the hot emission gases. Airborne measurements were carried out using both mapping and targeting acquisition modes. The later provides unique time-dependent information such as the gas cloud direction and velocity.

9242-24, Session 5

GreenHouse Observations of the Stratosphere and Troposphere (GHOST): a novel shortwave infrared spectrometer developed for the Global Hawk unmanned aerial vehicle

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The tropospheric distribution of greenhouse gases (GHGs) is dependent on surface flux variations, atmospheric chemistry and transport processes over a wide range of spatial and temporal scales. Errors in assumed atmospheric transport can adversely affect surface flux estimates inferred from surface, aircraft or satellite observations of greenhouse gas concentrations using inverse models. We present a novel, compact shortwave infrared spectrometer (GHOST) for installation on the NASA Global Hawk unmanned aerial vehicle to provide tropospheric column observations of CO2, CO, CH4, H2O and HDO over the ocean to address the need for large-scale, simultaneous, finely resolved measurements of key GHGs. These species cover a range of lifetimes and source processes, and measurements of their tropospheric columns will reflect the vertically integrated signal of their vertical and horizontal transport within the troposphere. The primary science objectives of GHOST are to: 1) provide observations which can be used to test atmospheric transport models; 2) validate satellite observations of GHG columns over oceans, thus filling a critical gap in current validation capabilities; and 3) complement in-situ tropopause transition layer tracer observations from other instrumentation on board the Global Hawk, providing a link between upper and lower troposphere concentration measurements.

The GHOST spectrometer system comprises a target acquisition module (TAM), a fibre slicer and feed system, and a multiple order spectrograph. The TAM design utilises a gimbal behind an optical dome, which is programmed to direct solar radiation reflected by the ocean surface into a fibre optic bundle. The fibre slicer and feed system then splits the light into the four spectral bands using order sorting filters, with the fibres corresponding to each band arranged with a small sideways offset such that each spectrum is correctly centred on the detector array. The spectrograph design is unique in that a single grating and detector is used for all four spectral bands. The whole instrument is housed within a liquid nitrogen cooled cryostat to ensure thermal stability.

The radiometric and spectral calibration planned for GHOST will take place at the UK Astronomy Technology Centre (ATC) prior to its maiden flight on board the Global Hawk. The spectral calibration will use a combination of emission lamps and tuneable monochromatic light sources to provide absolute and relative wavelength references, respectively, as well as characterisation of the instrument line shape. In addition to providing an outline of the science rationale, instrument design and calibration scheme for GHOST, we evaluate the expected performance of the GHOST design using detailed optical simulations to estimate spectrometer characteristics, such as signal to noise ratio and spectral response. This information is used in conjunction with a radiative transfer model to simulate radiance spectra that might typically be measured using GHOST to observe reflected sunlight during a Global Hawk mission over the Pacific Ocean. The calculated radiance spectra

are used to demonstrate the potential of GHOST for retrieving tropospheric greenhouse gas columns, by using an optimal estimation retrieval code based on a methodology developed for the retrieval of total GHG columns from GOSAT and OCO-2 observations.

9242-25, Session 5

Acoustic atmospheric tomography using multiple unmanned aerial vehicles

Anthony Finn, Kevin Rogers, Univ. of South Australia/ Defence & Systems Institute (Australia); Joshua Meade, Univ. of South Australia/Defence & Systems Institute (Australia); Stephen Franklin, Univ. of South Australia/ Defence & Systems Institute (Australia)

This paper presents a method for tomographically reconstructing atmospheric temperature profiles and wind velocity fields based on parasitic acoustic travel time measurements observed between two or more Unmanned Aerial Vehicles (UAVs). The atmospheric profile is derived using a multi-stage process. Firstly, a combination of narrowband signal processing and spatial integration is used to remove both the narrowband tones of the sensing UAV's engine firing sequence and propeller blade rate and the wind flow noise over the microphones. Then beam forming techniques are used to detect and track the dominant spectral lines of the other UAV. These tones, which are measured by and shared between both aircraft, are then combined to determine the sound wave travel times from the Doppler shift for sound waves from one UAV to the other. UAV flight profiles must then be engineered so that the rate of change of range – and hence Doppler shift – is unique. The estimated sound travel times are then used to derive the atmospheric temperature and wind profile using tomographic inversion. The technique offers extended mobility beyond ground-deployed sensor techniques and the capacity to monitor hazardous atmospheric environments, otherwise not justifiable on the basis of cost or risk. This paper reports on the results of preliminary field trials and simulations and describes the anticipated performance of the technique.

9242-26, Session 5

3D acoustic atmospheric tomography

Kevin Rogers, Anthony Finn, Univ. of South Australia/ Defence & Systems Institute (Australia)

This paper presents a method for tomographically reconstructing spatially varying 3D atmospheric temperature profiles and wind velocity fields based. Measurements of the acoustic signature measured onboard a small Unmanned Aerial Vehicle (UAV) are compared to ground-based observations of the same signals. The frequency-shifted signal variations are then used to estimate the acoustic propagation delay between the UAV and the ground microphones, which are also affected by atmospheric temperature and wind speed vectors along each sound ray path. The wind and temperature profiles are modelled as the weighted sum of Radial Basis Functions (RBFs), which also allow local meteorological measurements made at the UAV and ground receivers to supplement any acoustic observations. Tomography is used to provide a full 3D reconstruction/visualisation of the observed atmosphere. The technique offers observational mobility under direct user control and the capacity to monitor hazardous atmospheric environments, otherwise not justifiable on the basis of cost or risk. This paper summarises the tomographic technique and reports on the results of simulations and initial field trials. The technique has practical applications for atmospheric research, sound propagation studies, boundary layer meteorology, air pollution measurements, analysis of wind shear, and wind farm surveys.

9242-27, Session 5

DOAS measurements of air pollutants including HCHO near road traffic

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Emission sources as well as wind speed and direction and MLH are important factors which influence high air pollutant concentrations. This is generally known (Schäfer et al., 2006) but the detailed understanding of processes directing certain air pollutant concentrations like HCHO is not complete. To study these processes a long-term campaign in Augsburg, Germany, is performed since March 2012.

The concentrations of NO, NO2, O3 and HCHO are measured with a DOAS from OPSIS across main traffic roads at a crossing as well as a main traffic road and a nearby park area at a second site. In situ concentrations of CO, NO, NO2 and O3 are measured at the crossing also. A ceilometer CL31 from Vaisala which are eye-safe commercial mini-lidar systems is applied to detect layering of the lower atmosphere continuously. Special software for these ceilometers with MATLAB provides routine retrievals of lower atmosphere layering from vertical profiles of laser backscatter data. Meteorological data were measured by a ground-based weather station at the measurement site as well as taken from monitoring data archives of the German National Meteorological Service (DWD), measured by a weather station at the airport Augsburg and by radiosondes (Oberschleißheim).

Correlation analyses are applied to show the coupling of temporal variations of NO, NO2, O3 and HCHO concentrations with MLH and wind speed. HCHO which is emitted from both anthropogenic and biogenic sources is studied especially.

9242-28, Session 5

Measurements of formaldehyde total content using DOAS technique in Moscow Region: retrieval method and first results

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MAX-DOAS measurements are the possible source of gas vertical distribution in the atmosphere. We developed earlier a method for determination of the formaldehyde total content retrieval in cloudless. A new algorithm applicable for overcast and its error analysis is presented. The data are retrieved from UV spectra of the scattered solar radiation measured by the MAX-DOAS instrument developed by JAMSTEC at Zvenigorod, Moscow Region, Russia.

The variability of the HCHO vertical column in 2010 is analyzed. It was obtained basing on retrieval in cloudless that the HCHO vertical column density is larger during east wind directions than during non-east wind directions. It can be associated with Moscow Megacity influence on air quality at Zvenigorod. The estimation of Moscow Megacity influence on HCHO abundance at Zvenigorod is around 2.5?1014 molec cm-2 per 1 km length of trajectory path inside Moscow Ring Road. A temperature effect is noticeable in the HCHO VCD. Our data show statistically significant positive temperature effect in HCHO for the background condition for temperatures from –5 °C to +33 °C. The temperature trend in HCHO data at Zvenigorod Scientific Station is about (8.9±2.3)?1014 molec cm-2/°C. The increase of the HCHO VCD during increase of the air temperature can be explained by the HCHO formation from non-methane biogenic volatile organic compounds (e.g. isoprene) for which more emission is expected at higher temperatures, and by growth of areas of forest and turf fires.

9242-29, Session 6

Dimensionless parameters for lidar performance characterization

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Extending previous work by Agishev et al.1-3, a set of two dimensionless parameters is proposed to characterize lidar systems from the energy point of view. They are based on an asymptotic approximation of the output signal-to-noise ratio as a function of the input optical power reaching the photoreceiver when there is no background radiation. One of them is defined as the ratio between the input power level coming from a reference range in a reference atmosphere and the input power level that would produce a reference output signal-to-noise ratio if the photoreceiver operated always in signal-shot-noise limited regime. The other is defined as the ratio between the input power level coming from a reference range in a reference atmosphere and the input power level for which the signal-induced shot noise power equals the receiver noise power. With only these two parameters a good approximation to the output signal-to-noise ratio of the lidar under no-background conditions can be calculated as a function of the fade with respect to the power reaching the photodetector in the reference situation. These parameters can also be used to compare and rank the performance of different systems. Examples of these uses will be given in the presentation.

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9242-30, Session 6

Estimates of cumulative rainfall over a large area by weather radar

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In this work we propose a technique for the measurement of 15 minutes cumulative rainfall maps, applied over the Tuscany area, using both the italian and regional weather radar networks together with the regional raingauge network.

The used radars provide the reflectivity measurements every fifteen minutes with a resolution of 1 km square pixels or better. To estimate the 15 minutes cumulative rainfall on the image pixels we have applied a standard Marshall Palmer relationship to convert the radar scan reflectivity (Z) to instantaneous rain-rate (R) and we have made an averaged integration between two consecutive radar observations.

To assess the radar-based rainfall estimates accuracy we have compared them with time and space coincident raingauge measurements. As the raingauges observation are affected by an error much smaller than that of radar measurements, it can be considered negligible for our purposes.

Comparison between radar and raingauge observations is very critical as radar measurements are referred to the volume cells, while the raingauge measure can be considered punctual as it collects the rain over a very small area (only a few square decimeters). Moreover the Marshall Palmer Z-R relationship introduces an additional uncertainty on the rainfall estimates.

To confirm this, the results of this comparison using the raingauge point observations and the time-space coincident radar pixel estimates for several case studies has shown a very high variance of the radar raingauge difference. Certainly some of the causes of that have to be found in the complex orography of the area under study and in the spatial inhomogeneity of the rain gauges network. Moreover the two observations measurements are not time homogeneous: in fact raingauges provide time cumulative measurements while radars collect instantaneous observations.

To make comparable the observations given from these two types of sensors, we have collected cumulative rainfall over areas a few tens of kilometers wide. Over these areas the radar cumulative rainfall is given by the sum of the pixel estimates included in this box surface, and the raingauges cumulative rainfall is given by spatialisation of raingauge measurements. The method used has been the Ordinary Block Kriging, which has allowed to evaluate the cumulative rainfall along with its uncertainty. The comparison results have shown a good correlation between the cumulative rainfall data obtained from the raingauges and those obtained by the radar measurements.

These results are encouraging in the perspective of using the radar observations for near real time cumulative rainfall nowcasting purposes. Indeed radar observations are very often used for the detection and monitoring of severe weather system dynamics, as they provide a high frequency (15 minutes) multi-levels (several elevations scans) spatial widespread atmospheric observation from a ground based point. The joint use of satellite instruments as SEVIRI sensors on board of MSG-3 satellite can add relevant information on the nature, spatial distribution and temporal evolution of cloudiness over the area under study. For this issue we have used several MSG-3 channel images which are related to cloud physical characteristics or ground features in case of clear sky.

9242-31, Session 6

Validation of atmospheric correction algorithm ATCOR

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Atmospheric correction of satellite images is necessary for many applications of remote sensing, i.e. computation of vegetation indices and biomass estimation. The largest uncertainty in atmospheric correction arises out of spatial and temporal variation of aerosol amount and type. Therefore validation of aerosol estimation is one important step in validation of atmospheric correction algorithms.

Our ground-based measurements of vertical column aerosol-optical thickness (AOT) spectra were performed synchronously to overpasses of satellites Rapid-Eye, Landsat 7 and Landsat 8. Validation of aerosol retrieval by the widely used atmospheric correction tool ATCOR was then realised by comparison of AOT derived from satellite data with the ground-truth.

Mean uncertainty is ?AOT550 ≈ 0.05, corresponding approximately to uncertainty in surface albedo of ?? ≈ 0.005. Generally, ATCOR derived AOT values are mostly overestimated when compared to the ground-truth measurements. Very little differences are found between Rapid-Eye and Landsat sensors. Differences between using rural and maritime aerosols are negligible within the visible spectral range.

9242-32, Session 6

Using Lunar observations to validate in-flight calibrations, pointing accuracy and detector alignment of CERES instruments

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The validation of in-orbit instrument performance requires stability in both instrument and calibration source. This paper describes a method of validation using lunar observations scanning near full moon by the Clouds and Earth Radiant Energy System (CERES) instruments. Unlike internal calibrations, the Moon offers an external source whose signal variance is predictable and non-degrading. From 2006 to present, in-orbit observations have become standardized and compiled for the Flight Models-1 and -2 aboard the Terra satellite, for Flight Models-3 and -4 aboard the Aqua satellite, and beginning 2012, for Flight Model-5 aboard Suomi-NPP. Instrument performance parameters which can be gleaned are CERES calibration validation, telescope pointing accuracy, detector alignment and static point response function validation. Lunar observations are used to examine the stability of all three detectors on each of these instruments from 2006 to present. This validation method has yielded results showing trends per CERES data channel of 1.2% per decade or less. The maximum pointing accuracy error was found to be 0.05 degrees in azimuth and 0.03 degrees in elevation angle, and detector alignment was within 0.1 degrees for all cases and within 0.02 degrees for most cases.

The Moon is a useful, independent calibration target and provides an extremely stable surface. CERES detectors register the signal output reflected off of the entire face of the Moon, but lunar irradiance is small compared to the dynamic ranges of the CERES channels. The size of the Moon's image within the FOV varies with respect to lunar distance from the Earth. Solar irradiance on the Moon varies with respect to solar distance. Lunar librations and phase angles result in viewing the Moon from different directions and with different solar illumination over the observed surface. These effects create a variation in lunar irradiance of 20% in the total channel and 8% in the shortwave channel. However, these variations are systematic. Although variations in irradiance at first appear to render lunar observations too chaotic as a dependable resource for CERES calibration, knowledge of lunar orbital data reveals systematic, mathematical methods to remove most of these variations. The CERES instruments are found to measure lunar irradiance with consistent high precision which is revealed as each orbital effect is removed. By using a stable, predictable, independent source, calibration source instability can be removed from the equation. Without an independent and stable source, it is unknown if the on-board calibration devices have changed over time. This study provides a capability to identify and adjust for these changes, thereby assisting in the validation of CERES instrument detector stability and improving the quality of the CERES data used to detect climate change. The lunar observations also provide validation that the three channels remained aligned through launch. The alignment of the shortwave and longwave channels with the total channel is the difference between their directions to the Moon. The technique also validates the alignment of the three channels of each instrument. Telescope alignment was taken to be the difference of the azimuth and elevation of the Moon between the Total channel and the Shortwave and Longwave Window channels. In all cases, the alignment was within specifications. In several cases, an annual cycle was found in the alignment. The difference of elevation angles is used to compute the cross-track geolocation error of the CERES footprints. For all four instruments, the cross-track error is less than 2 km, which is an order of magnitude smaller than the footprint size. These results agree with studies using coast-line detection to 1.4 km or better. Lunar observations are not sensitive to misalignment in the direction which would cause errors along-track in geolocation near nadir. At large distances from nadir, the azimuth error will cause an error. The lunar and coastline techniques supplement each other for computing pixel location errors away from nadir. The azimuth errors are 0.17o or less, which is an order of magnitude less than the 2.6o width of the field of view.

9242-33, Session 6

Comparison of unfiltered radiances measured by CERES instruments aboard the NPP and Terra/Aqua satellites

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In order to compare CERES instruments on the NPP and Terra/Aqua satellites, several data collecting strategies have been designed. They are based on orbit characteristics and scanner capabilities. They are referred to as (i) simultaneous Earth observations, (ii) matched sites targeting, and (iii) minor plane radiation measurements; they are briefly described in the next section. Since two of them require putting instruments into a special scanning mode and profile, predictions are based on satellite ground track files available for 35 days in advance. A full paper will elaborate on comparison data collection using these strategies, and report preliminary results of comparing unfiltered radiances of SW and LW ERBE-like (ES8) data products.

SIMULTANEOUS EARTH OBSERVATIONS. This is a strategy that is readily available for the instruments on board the NPP and Aqua satellites. The NPP and Aqua satellites are in 98.6o and 98.2o sun-synchronous, ascending orbits, at 825km and 705km altitude, respectively. Their equatorial crossing time is 1:30PM, therefore, every 64 hours they fly "in tandem" only separated by a few degrees in the geolocation of their groundtracks. Specifically, for about 20 minutes, the groundtracks of both satellites are within 1o latitude and 2o longitude. Data collected within this strategy are processed on a 1o ? 1o grid to analyze differences in averages. There is already a full repeat cycle (432 days) of comparison data that can be used to evaluate the differences between FM3 and FM5 scanners.

MATCHED SITES TARGETING. A unique comparison opportunity is available when groundtracks of the NPP and Aqua satellites are within a 0.25o, and less than 5 minutes apart. These opportunities present themselves less than 10 times per months; however, they offer a comparison of very high precision data. Each opportunity lasts about 2 minutes, and the comparison is at a footprint level. Scanners on both satellites are operating in a nadir dwell scan profile that produces 330 footprints along their respective overlapping groundtracks. There have been collected comparison data for several different scene types including snow/ice, ocean, and land.

MINOR PLANE RADIATION MEASUREMENTS. This strategy is devised for comparing measurements taken by FM5 and FM1 and FM3. Since there is a common projection point on the groundtracks of all three satellites at about 68oS and 68oN, this configuration offers another comparison opportunity. The time differential between Terra and Aqua is 15 minutes on every orbit, NPP arrives at that point 5 minutes apart from Terra on 3-4 consecutive orbits, but 2-3 days apart. The best comparison viewing direction is in the minor plane, and all three instruments scan in this direction using a double nadir scan profile for about 2 minutes. Annual data collection takes place during the summer solstice, and the first campaign was run in the summer of 2012 followed by one more in 2013.

9242-34, Session 6

Study of clear-air dynamic turbulence structure in troposphere using wind profile radar

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Wind profile radar is an instrument often used for remote sensing the wind structure of troposphere. Under the clear-are condition, the wind profiler radar receives the backscatter of atmospheric turbulence eddies. The return signal of radar brings abundant information of turbulence. From the spectrum of backscatter, The Doppler frequency shift of radar echo spectrum is usually used to calculate the wind speed size, echo spectrum intensity is usually used for the calculation of turbulent structure constant of refractive index. Radar echo spectrum intensity will not only change due to atmospheric turbulence effects, its width is also affected by the turbulent conditions. Wind velocity fluctuation and the uneven will cause the radar reflection volume of wind is not consistent, this is one of the reasons why the echo spectrum broadening.

The reason of radar echo spectrum broadening is analyzed in this paper. The method of achieving atmospheric wind structure constant based on the echo spectrum width after numerical analysis. The wind structure constant is used to be considered as an important parameter of dynamic structure of turbulence.

At the last part of this paper, the characteristic of troposphere dynamic turbulence is described after the analysis of measurement data. The results show the strength of dynamic turbulence decreases along with the increase of the height, the lapse rate of which in the night is more rapid, and the velocity structure constant has remarkable diurnal variability at the top of boundary layer.

9242-36, Session 6

Algorithms comparison for calculating downward longwave radiation by MODIS data under clear and cloudy skies

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Downward longwave radiation (DLR) at the earth's surface is a major component of surface radiation budget and thus the climate, and remote sensing provides the most effective method to get surface DLR on a large scale. This paper presents a comparison of several DLR algorithms for both clear-sky and cloudy-sky conditions. These algorithms were applied to MODIS Terra data and extensively validated using one year's ground data at 13 stations around globe. Furthermore, the different sources of atmospheric product, which including MODIS product and NCEP operational global analysis data, were assessed in clear-sky DLR estimation.

For clear sky conditions, five algorithms including hybrid algorithm and empirical algorithms were used. These algorithms are Tang&Li algorithm and Wang&Liang algorithms that use satellite observed thermal radiances, Yu2013 algorithm that uses satellite brightness temperature and water vapor content, and Zhou-Cess algorithm and Gupta2010 algorithm that use atmospheric parameters. The input atmospheric parameters of all the algorithms including air temperature, water vapor and atmospheric profiles were from MODIS atmospheric products. The validation result indicated that Tang&Li algorithm and Wang&Liang algorithm that only use satellite thermal radiance have significant positive errors over arid regions, which was caused by the difference between surface skin and air temperature; Yu2013 algorithm performed better because that the difference between air and surface temperature was accounted in the algorithm. Over high altitude regions, Zhou-Cess algorithm and Gupta2010 algorithm often underestimated DLRs because the two algorithms are affected by uncertainty of the near surface air temperature, Yu2013, Tang&Li and Wang&Liang algorithms could avoid the error of air temperature. On the base of above study, Yu2013 algorithm is commend in DLR estimation.

Then MODIS and NCEP atmospheric profiles were compared in clear-sky DLR estimation. We found that MODIS atmospheric profile often lacks the information of near surface layer in high altitude regions, which caused the underestimation of air temperature, thus DLR would be underestimated. After using NCEP derived parameters, the performance of Gupta2010 and Zhou-Cess algorithms were greatly improved in high altitude regions; Yu2013 algorithm also had better performance, but it was less affected by NCEP parameters compared with the Gupta2010 and Zhou-Cess algorithms. Yu algorithm performed not well in the conditions with extreme climate, such as winter season of polar region and the site in tropical Pacific; however, using NCEP parameter improved the results. Thus NCEP derived atmospheric parameters other than MODIS were commended in high attitude regions and the conditions with extreme climate.

For cloudy conditions, three algorithms that determined cloud radiative force by cloud base temperature, including Gupta2010 algorithm, Schmetz1986 algorithm and Diak2000 algorithm, and Zhou-Cess empirical algorithm that employs cloud water path and cloud ice path were used. A test dataset was simulated by MODTRAN and changing important cloud parameters in cloud model. The testing dataset was first used to calculate the model errors of these algorithms supposing input parameters were accurate, and the results indicated that DLRs from the algorithms based on cloud base temperature had good consistency with actual DLRs, but were slightly overestimated. Then the algorithms were applied to actual MODIS Terra data, the cloud parameters were from MODIS cloud products, and meteorological parameters and atmospheric profile were from NCEP data. The validation results indicated that accuracy of DLR for the algorithms based on cloud base temperature was greatly influenced by cloud base temperature and cloud fraction, while Zhou-Cess algorithm had best results in most of the sites and the uncertainties of cloud parameters had very little impact on the algorithm. Therefore, Zhou-Cess algorithm was suggested for cloudy-sky DLR calculation.

9242-37, Session 6

Estimation of all-sky downward shortwave radiation from MTSAT-1R images and MODIS data

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Downward shortwave radiation (DSR) is an important parameter of land surface radiation budget and climate research. This paper presents a methodology to estimate DSR using hourly geostationary satellite (MTSAT-1R) and MODIS BRDF albedo product (MCD43C1). The proposed algorithm retrieves atmospheric parameters directly from MTSAT-1R images by searching and interpolating look-up tables (LUT), which are created by the SBDART (Santa Barbara DISORT Atmospheric Radiative Transfer). Surface reflectance is derived by selecting the lowest pre-corrected reflectance (also referred to as "the clearest surface reflectance") with the observed time period for each satellite observation time of the day. The cloud detection was performed using the coupled Cloud Depiction and Forecast System model (d'Entremont et al., 2003). The total precipitable water is derived using the split-window algorithm under cloud-free conditions (Chesters et al., 1987). The aerosol optical thickness is derived using a LUT and the visible channel of MTSAT-1R images under cloud-free conditions. The diurnal surface reflectance in combination with a LUT is used to derive cloud optical thickness under cloudy sky. The total precipitable water and aerosol optical thickness are determined to be invariable in creating the LUT for cloudy sky DSR retrieval. Sensitive analysis of the DSR retrieval shows that the cloud height and the cloud droplet effective radius have little impact on the downward shortwave radiation

comparing with the cloud optical thickness, and hence a fixed cloud height and effective droplet radius are used. The aerosol optical thickness, total precipitable water and DEM are used to calculate the instantaneous DSR under clear sky. The derived cloud optical thickness together with surface albedo and DEM are used to calculate the instantaneous downward shortwave radiation under cloudy sky. Hourly and daily DSR is calculated by the diurnal cycle integration of hourly instantaneous downward flux.

The retrieved daily DSR is compared with ground-based measurements at 96 stations from China Meteorological Administration (CMA). The results show that the estimated DSR is in good agreement with ground measurements over China with a correlation coefficient of 0.93 and a mean bias of 5.8%. Root-mean square differences in the daily DSR are 20.7% for all sky conditions. The daily DSR is also compared with observations on Tibetan Plateau, and the results shows a correlation coefficient of 0.91 and a mean bias of 1.53%. Root-mean square differences are 17.5%. Results show that the proposed model is sensitive to the aerosol type. The mean bias error is -9.37% and the root-mean square difference is 22.68% for urban aerosol model. The differences between the satellite derived estimates and ground observations may be attributed to calibration uncertainty of the satellite sensor and the ground instruments, undetected cloud shadows, steps of the LUT parameters, uncertainty in determining surface reflectance, and errors in ground observations. Furthermore, the inadequacy of the parallel-plane assumption in the radiative transfer calculations at large solar zenith angles may lead to larger uncertainties.

9242-60, Session 10

Characteristics of turbulence-driven atmospheric blur over coastal water

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From November 2009 until October 2010, high resolution imagery was taken day and night (24/7) of point sources over a range of 15.7 km over coastal water near Simon's Town (South Africa). The data provide statistics on the mean value and the variation of the atmospheric point spread function (blur) during series of 150 consecutive frames. This blur is directly related to the atmospheric modulation transfer function, determining range information. This parameter is of key operational importance for the user of optical sensors in similar areas, for example in anti-piracy operations. The blur is characterized by the second and higher moments of the intensity distribution, which result in point- and line spread functions (PSF and LSF) in X and Y-direction. Analysis of the frame series provides the temporal characteristics of the blur, including beam wander and scintillation index. For better understanding of the results via models, weather data were collected on various locations, as relevant for the turbulence conditions: air- and sea temperature, windspeed and -direction, relative humidity and the structure parameter for refractive index: Cn2. Additional information on the intervening atmosphere was obtained from atmospheric refraction-, transmission- and scintillation data, collected simultaneously along the same path. Results are presented for a representative set of data on blur, beam wander and scintillation collected during the campaign. Attention is spent on the problems, rising with the definition and collection of various types blur data. The impact of the results on the classification ranges of elctro-optical sensors in coastal waters is discussed.

9242-61, Session 10

Investigation of optical turbulence in the atmospheric surface using scintillometer measurements along a slant path and comparison to ultrasonic anemometer measurements

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Optical turbulence represented by the structure function parameter of the refractive index Cn2 is a relevant parameter for the performance of electro-optical systems and characterization of the atmospheric influence on imaging. It was investigated during a field trial above a Highveld grassland in the atmospheric surface layer at the Rietvlei Nature Reserve close to Pretoria in South Africa from 18th June to 30th June 2013. This campaign was performed to compare different measurement techniques during analyzing the development of the vertical distribution of optical turbulence up to a height of 16 m above ground. The chosen time period was characterized by a pronounced diurnal cycle of the meteorological conditions, i.e. low variations from day to day. Ultra sonic anemometers were used to measure high frequency time series (50 Hz) of temperature at single points. From the statistical analysis of these time series Cn2 was derived. Three instruments were mounted at a portable mast in the center of slant path measurements over a horizontal distance of 1000 m using large aperture scintillometers (Boundary layer scintillometer BLS 900). Averaging over a time period of 5 minutes, the results of both methods are compared. The agreement in the results of optical turbulence is quite good. Discrepancies and agreement are analyzed with respect to the atmospheric stability and other meteorological parameters. Lowest values at 4.6 m above ground amount to about 8*10-17 m-2/3.and daily maxima to 6*10-13 m-2/3. Additional to the nearly constant meteorological conditions in the diurnal cycle, the uniformity of the terrain let the results of this measurement campaign an ideal data set for investigating methodological questions regarding a comparison of single point measurements with integrated measurements over a horizontal distance. Four stability regimes were identified in the diurnal cycle and investigated. These are convective conditions during the day, neutral conditions about sunrise and sunset, and two different stable regimes at night.

9242-62, Session 10

Exploration of satellite-derived data products for atmospheric turbulence studies

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The quality, availability and diversity of satellite-derived earth observation data products are continuously improving. Such satellite products can provide an extensive and complementary view on many matters with respect to intensive but localised in-situ or ground measurements. A search has been undertaken on the available types and sources of satellite data products that could be applicable in the study of the spatio-temporal distribution of aero-optical turbulence in the atmospheric boundary layer. This has included all satellite data products that are relevant to the surface heat balance such as surface reflectance, temperature and emissivity. It was also important to identify active archive data services that can provide pre-processed and quality-filtered time-series products. Products derived from the Moderate Resolution Imaging Spectrometer (MODIS) and other sensors on the NASA Terra and Aqua platforms were of special interest. The use of climatological shortwave and longwave radiative transfer models, combined with satellite-derived data was explored as a method of elucidating the surface heat balance. An in-situ dataset from the Rietvlei vertical turbulence profiling campaign of 2013 was used to validate a number of aspects of the satellite-derived heat balance approach.

9242-63, Session 10

Experimental verification of optical crosswind measurement systems

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A series of experiments have been conducted to evaluate the accuracy of single station, optical systems for measurement of average crosswind velocity. By analyzing the spatial-temporal cross-correlation function of signals caused by turbulence-induced refractive index irregularities, the wind velocity

perpendicular to the line of sight is determined. This method allows also for direct measurement of the turbulence structure parameter Cn2 by the angle-of arrival technique. These real-time turbulence values are incorporated into the wind vector estimation to achieve higher accuracy. The evaluated systems include an active technique which measures the backscatter of the transmitted laser pulses and a passive technique where the naturally illuminated scene serves as the light source. Both active and passive systems have been compared to a series of ultrasonic anemometers located along the measurement path. The experiments were performed along a uniform path in various locations. Very good fits (about 0.5 m/sec) have been obtained at all turbulence conditions along a 1000m path.

9242-64, Session 11

Experimental setup for investigation of laser beam propagation along horizontal urban path

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It is well known that a laser beam propagating through the air is affected by atmospheric turbulence. In this paper, we built-up an experimental setup for laser beam propagation along horizontal urban path that can be useful for applications such as free space laser communications. The setup includes a telescope to focus a laser beam on a retro-reflector, which is located 410 meter away, and the optical test bench able to measure intensity fluctuations, at the pupil telescope, of the reflected beam. In addition, in weak turbulence regime, we show experimental data of scintillation and their agreement with theory. Another goal of this project was to test the susceptibility of the SH sensor to scintillation. We also tested the influence of possibly non-Kolmogorov turbulence on measured statistical parameters like structure function or scintillation index.

9242-65, Session 11

Position determination of a point source through turbulent atmosphere

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The reliable tracking of fast-flying distant objects such as rockets, artillery and mortars (RAM) or UAVs is necessary for the implementation of threat-warning and counter measurement systems. Accuracies in the sub-?rad range are required for such tracking systems in real time applications, but are limited by atmospheric turbulence.

In this paper, we present results from measurement campaigns showing the influence of atmospheric turbulence on the apparent random motion and broadening of a point source by taking video streams of a stationary and moving point source.

At our test site we use an LED serving as a point source mounted on a highly accurate linear translation stage which can be accelerated to velocities up to 5 m/s. The motion of this point source is observed from a distance of 130 m by several imaging systems like photo objectives, spotter scopes or telescopes. Each imager is fixed on a rigid mount in order to isolate it from mechanical vibrations and gusts as well to ensure that the apparent random motion of the point source image is only caused by atmospheric turbulence.

The centroid of the point source was determined down to sub-pixel accuracy from the streams via post-processing the acquired videos considering the specific signal to noise ratio of the imaging system.

The local weather conditions were continuously monitored with a scintillometer to determine the relevant turbulence parameter Cn?. Our experimental data of the rms angular position jitter is compared for several values for Cn? with a theoretical model based on Kolmogorov theory taking the turbulence into account.

9242-66, Session 11

Influence of each Zernike aberration on the propagation of laser beams through atmospheric turbulence

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Atmospheric turbulence has a deleterious effect on the performance of optical systems. The atmospheric turbulence can be described using Zernike polynomial functions, also called Zernike modes. In this description each mode represents one specific aberration (tip, tilt, defocus, astigmatism ...) and the atmospheric turbulence is a weighted sum of these aberrations. In most of optical systems, and especially in the case of laser weapons or free-space laser communications, a correction of the aberrations induced by the atmosphere is necessary. We study numerically the influence of each Zernike mode on the propagation of a laser beam through the atmosphere by two different methods and for two different turbulence strengths. In both methods, we focus a laser beam on a target, or receiver plane, located at 2000 meter from the emitter. The atmosphere is simulated using the well-known phase screen method. The criterion used to assess the quality of the propagation is the intensity at the center of the receiver plane after a long term exposure.

In the first method, the phase screens are generated starting from the turbulence's power spectrum (von Karman spectrum). An idealized adaptive optics system is modeled to subtract a certain number of Zernike modes from the beam. At first, no correction is applied to the beam and the central intensity is computed. Then the first mode (tip) is corrected and the central intensity is computed. After each time the central intensity is computed, the next Zernike mode is subtracted from the beam in addition to the previous corrections. The evolution of the central intensity, with respect to the number of Zernike modes which were corrected, enables us to assess the influence of these aberrations.

In the second method, the phase screens are generated using the Zernike covariance matrix. Here, it is possible to adjust the strength of each Zernike mode directly when the phase screen is generated. But instead of changing the strength of each Zernike mode one at the time, we use a numerical space filling design. Each point of the design represents a set of strengths of the Zernike modes, which are used to generate the phase screens and therefore used to compute the central intensity. The study of the resulting intensity for each point of the design is then done by a linear discriminant analysis. It gives a linear function where the inputs are the strengths of the Zernike modes and the output is the central intensity. The coefficients of this function are therefore giving the importance of each mode: the greater the coefficient, the bigger the impact a small change of the aberration's strength on the central intensity.

The results from these two methods show that the influence of some Zernike modes is different whether the turbulence is weak or strong. In weak turbulence, the higher the Zernike mode, the less influence it has. But in strong turbulence, the influence of coma aberrations is becoming surprisingly important. We discuss implications of our results for the design of adaptive optics systems.

9242-68, Session 11

Modeling of laser beam propagation through turbulence

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Our approach for modeling laser beam propagation through turbulence involves parabolic equation method and results of experimental investigation in laboratory. We take into account density turbulent fluctuations only. The study consists of two parts. The first part is based on the analytic solution of the parabolic equation which is represented in the form of a series whose convergence has been proved (O. A. Nikolaeva, F. V. Shugaev, published in Doklady Mathematics, 2014, Vol. 89, pp.1-3, Pleiades Publishing, Ltd.). The solution depends on the refractive index, i.e. on the gas density. The density distribution can be found from the system of the Navier-Stokes equations. The appropriate solution can be constructed by two ways: (i) as a series in powers of vorticity which is supposed to be small at initial instant; (ii) with the aid of the parametrix method together with an iterative procedure, the results being valid for arbitrary value of the initial vorticity. In the first case we have a parabolic system with constant coefficients and a known right-hand term. In the second case we have a linear parabolic system, the coefficients at higher derivatives depending on the values which were obtained at previous iteration. The zeroth iteration corresponds to the initial conditions of the problem. The initial conditions are as follows. We suppose the vorticity to have non-zero values only inside vortical structures (vortex rings), the density and temperature being constant over the whole space at t =0. The solution of the Navier-Stokes equations is reduced to multiple integrals which have been evaluated with the aid of the Korobov grids. It follows from the solution that acoustic radiation arises, its frequency depending on the initial size of the vortex ring. Statistical properties of the propagating beam were found from the solution to the parabolic equation as average over time. As known, the spectrum of atmospheric turbulent fluctuations lies within the band from 1Hz to 1000 Hz (Tatarckii V.T., McGraw-Hill, N.Y., 1964). This corresponds to the vortex ring radii from 2 cm to 15 cm. We found finite-time-average of the intensity for beams propagating through sets of 3-5 vortex rings.

The second part of the study involves experiments in laboratory. The propagation path was equal to 7 m. The laser beam propagation was accompanied by convection (temperature gradient is equal to 15 C/cm) and lateral wind (v=0.5 m/s). The frequency of turbulent fluctuations was equal to 2-10 Hz . Frequency resolution was equal to 1kHz. Phase trajectories were obtained as well as statistical properties of the intensity of the beam in turbulent gas flow. The conclusion is as follows. Statistical characteristics traditionally used for the estimation of the laser beam spacial distortions in the open space data transmission channels are to be complemented by the dynamic parameters such as the space of embeddings dimension, characteristic frequencies for the phase trajectories and so on.

9242-74, Session 12

Correction methods for underwater turbulence degraded imaging

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The use of remote sensing techniques such as adaptive optics and image restoration post processing to correct for aberrations in a wavefront of light propagating through turbulent environment has become customary for many areas including astronomy, medical imaging, and industrial applications. EO imaging underwater has been mainly concentrated on overcoming scattering effects rather than dealing with underwater turbulence. However, the effects of turbulence have crucial impact over long image-transmission ranges and under extreme turbulence conditions become important over path length of a few feet. Our group has developed a program that attempts to define under which circumstances application of atmospheric remote sensing techniques could be envisioned. In our experiments we employ the NRL Rayleigh–Bénard convection tank for simulated turbulence environment at Stennis Space Center, MS. A 5m long water tank is equipped with heating and cooling plates that generate a well measured thermal gradient that in turn produces various degrees of turbulence. The image or laser beam spot can be propagated along the tank's length where it is distorted by induced turbulence. In this work we report on the experimental and theoretical findings of the ongoing program. The paper will introduce the experimental setup, the techniques used, and the measurements made as well as describe novel reference-free image quality metric that is applicable to image post processing and possibly to active aberration correction.

9242-75, Session 12

Scintillations in the imaging through turbulence

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Fluctuations in the images of scenes viewed over large distances are the most obvious manifestation of the turbulence effects on the imaging of the incoherent objects. While the average or long-exposure imaging is arguably the most well studied topic of the optical propagation in turbulence, and substantial progress was also made in understanding the average short-exposure imaging, the image scintillations for complex extended scenes are not well understood. We discuss some available results of the image scintillation theory and report on some recent progress in this talk.

Unlike the coherent beam wave scintillations where scintillation strength is mostly governed by the optical wavelength and propagation conditions, for imaging the aperture size is critical, and image fluctuations typically increase for larger apertures. As a result, strong fluctuations of the images are very common even for relatively short propagation paths. The compromise between the increased resolution and scintillation suppression is a design challenge that requires a good understanding of the image statistics.

Point spread function (PSF) as the image of the simplest, point source is the fundamental case of imaging through turbulence. Some basic statistics of the PSF fluctuations were recently discussed in (Charnotskii, Opt. Eng. 2012). We will review the principal results of this study in the talk. Unfortunately, fluctuations in the images of the extended objects and scenes require more detailed statistical description of PSF that is not available yet. It is known, however, that energy conservation, being an essential feature of the optical waves propagating through refractive turbulence, critically affects the image formation. This issue was recently revisited in (Charnotskii, Opt. Eng. 2013), where it was presented as a third constraint on the turbulent PSF in addition to the well-known band-limited and non-negative requirements. It was also indicated that the third constraint is of the utmost importance for the anisoplanatic imaging, which is typical for extended scenes viewed over horizontal paths. We will discuss some important implications of the third constraint on the imaging of the extended scenes. Specifically, third constraint specifies that refractive turbulence produces no fluctuations in the images of uniformly bright objects. Clearly, this implies that image fluctuations have to depend on the local contrast of the source, as well as on the turbulence strength and the imaging aperture size. As a result fluctuations in the images of the complex scenes are strongest at the locations of the bright spots, edges and other sharp contrast areas.

We will use a simple "step" model of a source with a straight brightness contrast edge to calculate the scintillation index in the image plane. We believe that this model provides a better insight into the scene scintillations than the commonly used PSF. We consider several propagation models including the most rigorous Markov approximation, and show that scintillations are concentrated near the edge and vanish in the uniformly bright areas. It appears that the traditional scintillation index description is not the most natural scale for the image scintillations. Instead, scintillations are scaled by the brightness contrast of the source, which can be readily derived from the image itself.

9242-76, Session 12

Anisoplanatic imaging simulations on GPU with IMOTEP

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IMOTEP is a GPU-based (Graphical Processing Units) software relying on a fast parallel implementation of Fresnel diffraction through successive phase screens. Its applications include active imaging, laser telemetry and passive imaging through turbulence with anisoplanatic spatial and temporal fluctuations. Thanks to parallel implementation on GPU, speedups ranging from 40X to 70X are achieved.

The present paper gives a brief overview of IMOTEP models, algorithms, implementation and user interface. It then focuses on major improvements recently brought to the anisoplanatic imaging simulation method.

The underlying idea was to take advantage of the computational power offered by the GPUs to estimate the spatial statistics of the PSF through large series of deterministic simulations with independent realisations of the turbulence. Specifically, in a first computational step, the PSF is numerically sampled in the object plane for a series of realizations of the turbulence on the optical path. By fitting a simple parametric model to each simulated PSF, spatial covariance functions are obtained for each of the parameters. A crude shifted-gaussian model was first implemented, thus requiring 3 parameters only: the PSF width and the 2D location of its centroid. In a second image processing step, the previously computed and stored covariance functions are used to generate matrices of blur and shifts and process input images according to them. The outputs are instantaneous images, with blur and deformation following the prescribed covariance functions.

While the phase screen propagation algorithm provides realistic PSFs, the initial simplistic gaussian model didn't retain any details, like "speckles" which leads to high-frequency content in short exposure images. While the goal of IMOTEP is to support the improvement of image enhancement algorithms, the correct representation of those transitory details with their spatial characteristic is crucial.

To go towards this goal, we recently implemented a new empirical model of the PSF, based on Principal Components Analysis (PCA), ought to catch most of the PSF complexity. During a new initial step, a set of principal components are now computed from a series of independent realizations of the PSF. In the second step, the coordinates of the PSF in this new basis are the parameters whose spatial covariance functions are estimated. The GPU implementation allows estimating and handling efficiently the numerous (up to several hundreds) principal components typically required under strong turbulence conditions. The third image processing step then provides realistic instantaneous images, fully accounting for anisoplanatic effects and complex PSFs. Preliminary results are presented and compared to real images. They show a good agreement in terms of spatial resolution at short exposure.

9242-77, Session 12

Ship plume modeling in EOSTAR

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The hot exhaust plumes of naval ships constitute a significant element of the overall ship signature in the electro-optical domain. To accommodate plumes in EOSTAR, a pathway is suggested that starts with a CFD-calculation of the plume's flow field. Subsequently, plume radiance calculations as well as transmission through the plume calculations of the background yield the signature. A trade-off must be made between the level of detail and calculation time, and methods must be found to ensure a certain level of generality in the plume modeling.

9242-69, Session 13

Characterization of the digital holographic wavefront sensor

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Correction of atmospheric effects on propagation of laser light can be achieved by adaptive optics systems. The systems in turn rely on accurate wavefront sensors which are their sub-components. For free-space laser communications and for tracking of high-speed airborne objects, when strong turbulence can be assumed, conventional wavefront sensing based on the Shack-Hartmann device is not effective. One reason comes from the error rate on the wavefront reconstruction algorithm. Error rate becomes significant with the onset of strong scintillation which will cause obscuration or saturation of sections of the detector. Another drawback of the Shack-Hartmann-based wavefront sensing is the time-consuming detector readout and post-processing algorithms, which decreases potentially achievable bandwidths. This limits the relevance of conventional wavefront sensing for applications where the observed source is moving fast through the atmosphere.

In this paper we characterize a promising wavefront sensing alternative, the digital holographic wavefront sensor (DHWS). The core of the sensor is a digital grating (realized as a computer generated hologram - CGH) encoded in a spatial light modulator (SLM). Modal decomposition of the wavefront onto the Zernike polynomials basis is carried out by the diffraction of the wavefront in the grating. Therefore, time-consuming wavefront analysis and reconstruction operations are eliminated. Moreover, the DHWS allows for the use of fast photodetectors which dramatically reduce the readout time. In addition, we also expect its performance to be independent of scintillation across a wide range of atmospheric conditions.

The working principle of DHWS is based on the storage of geometrically separated converging beams in a digital multiplex hologram. Each two of the beams are associated to the same specific Zernike aberration. One beam corresponds to modulation of the incoming wavefront with the maximum expected aberration (for a given mode), while the other beam corresponds to modulation with the maximum aberration of opposite sign. These beams are optically reconstructed by the incoming laser light of interest. Measuring the normalized intensity difference of the two converging beams corresponding to the same aberration, gives us the necessary information to obtain the strength of the corresponding Zernike mode.

The presented study focuses on the characterization of the DHWS for measuring the strength of several aberration modes We examine the response of DHWS to scintillation both experimentally and theoretically. Sensitivity to residual tip/tilt is verified, as is the influence of detector size. Small detectors translate to high sensitivity of the sensor but also to smaller tolerance of beam motion (tip/tilt error). Therefore, a trade-off analysis is presented. Finally, the characteristic sensor output curves of the DHWS are determined as well as the accuracy of the sensor for the case of defocus measurement.

9242-70, Session 13

Dual-mode wavefront detection sensor based on liquid crystal microlens array

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Based on a proposed electrically tunable liquid crystal (LC) micro-lens array (MLA) instead of a commonly used micro-

lens array with fixed focal length in a conventional type, a new prototyped Shack-Hartmann sensor is reported. The LC-MLA with 128x128 elements is fabricated by the methods of photolithography and hydrochloric acid etching. And it has a low applied voltage because of replacing an insulation glass layer with a polyimide (PI) layer. Its top patterned electrode is composed of 128x128 micro-circular holes. The diameter of each micro-circular hole is 50?m, and the center-to-center distance between neighboring lenses is 150?m, and the thickness of LC layer is 20?m. The typical parameters of the LC micro-lens include: the optical aperture of single lens being 50?m, the variance range of the focal length being 50 ~ 400?m, the operating voltage being 1.2~5.0Vrms, and the maximum focal spot size of 10?m. Composed of the proposed LC-MLA and a CCD, a new type Shack-Hartmann wavefront sensor can be got. Generally, in wavefront measurement, if the feature of larger measurement range is required, the MLA of the wavefront sensor, with a short focal length, is chose. On the other hand, if the feature of high measurement accurate is required, the MLA with a long focal length is chose. This will cause a serious problem that the larger measurement range and high measurement accurate can't be realized by the same MLA. In this way, the traditional wavefront sensor with a fix focal length MLA is only applied in a specific situation, and can't have adaptive feature to adapt different complicated situations. But this kind new wavefront sensor can solve the above problem. Except for adaptive switching from the working mode of larger measurement range to the working mode of high measurement accurate by changing LC-MLA focal length with different applied voltage, this wavefront sensor also has a dual-mode imaging feature with obtaining wavefront information of the target and it's two-dimensional optical intensity image at the same time. In order to verify the characteristics of the proposed wavefront sensor, an extreme optical experiment is designed, which introduces a enormous distortion wavefront. At this circumstance, the distortion wavefront is out of the maxim measurement range of the traditional wavefront sensor with a fixed focal length MLA. However, using proposed wavefront sensor, this situation beyond the range of the distortion wavefront can be solved by adjusting the applied voltage of LC-MLA to change it's focal length. Because of changing it's focal length, the out of range spots can be got on the CCD again. Then, with a reconstruction method, the three-dimensional information of the distrotion wavefront can be got. At the same time, the two-dimensional optical intensity image is also got by the same device. From the above experiments, we can prove that the proposed wavefront sensor can effectively improve detection sensitivity and dynamic measurement range of wavefront. And results of the prototype demonstrated qualitatively verify this feasibility. This kind new type wavefront sensor will have a wide variety of applications in adaptive optics.

9242-71, Session 13

Simulation of SNS effect on the detecting precision of Hartman-Shack sensor

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Adaptive Optics system can be used to detect and compensate the aberrational wavefront of beam in real time. The compensative ability will be affected by the detecting precision of wavefront. Noise is one of the most important factors that affect the detecting precision of Hartman-shack sensor. Noise can induce the errors of centroid detected by HS sensor, consequently influences the wavefront reconstruction. Based on the characteristic of CCD, the model that simulates the detecting precision of wavefront affected by noise is built. And by contrasting the simulated results with the experiment, the model is modified and validated. For typical HS sensor, the effects of noise on the detecting precision of wavefront is simulated, and the relations of wavefront detecting precision with the Signal-to-Noise(SNR), the expansibility of beam spot in CCD, and the number of pixel used to calculate spot centroid are analyzed. Several results that can be used in engineering application are obtained.

9242-73, Session 14

Optically addressed and submillisecond response phase only liquid crystal spatial light modulator

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Liquid crystal based phase only spatial light modulator has attracted many research interests since last several decades because of its advantage of low operating voltage, small volume, high resolution, low consumption and light weight. Until now the liquid crystal spatial light modulator has been applied in many fields, such as adaptive optics, laser beam shaping and laser beam steering. But the response speed of nematic liquid crystal often limited its application. In this paper, an optically addressed phase only liquid crystal spatial light modulator was proposed based on polymer network liquid crystal. The schematic of the configuration was shown in Fig.1, in which 7wt% RM257 and 0.5wt% IRGA819 photo-initiator was dissolved in the liquid crystal solvent of HPC851900. To obtain phase modulation with polymer network liquid crystal, light scattering and addressing has been the bottleneck to achieve ultrafast phase modulator. Morphology effect on the light scattering property was first elucidated based SEM analysis. The light scattering of polymer network liquid crystal with different polymerization temperature was shown in Fig.1 and the corresponding morphology of the polymer network in each sample was shown in Fig.2. It was indicated that the polymer network liquid crystal in which the morphology was of small unit size possessed the smallest light scattering intensity. The effect of the other polymerization conditions was also studied, such as the UV curing intensity and polymerization time. The morphology of the studied polymer network liquid crystal was mainly consisted of two categories, namely cross linked fibrils and cross linked fibril bundles. The formation of fibril bundles usually increased the unit size of polymer network which usually induced more light scattering, while the latter reduced the unit size of polymer network and induced smaller scattering intensity. But the formation of cross linked fibrils can not endure high applied voltage, and electro-striction effect was often found when high voltage was applied, which was disadvantageous for achieving submillisecond response for phase modulation. Hence there is a tradeoff between the light scattering and submillisecond response for phase modulation. Another concern was on the addressing issue. It was well known that the IC driver can not afford the high voltage needed to achieve full wavelength phase modulation, unless in the case of PDP displayer. In another aspect, the optically addressing has always been one of the most fascinating addressing methods. To drive the polymer network based phase modulator, optical addressing method was selected as shown in Fig.1. The photo-conductor BSO crystal was employed to be inserted between the liquid crystal layer and glass substrate to afford the optical addressing ability. The optically addressing phase modulation was shown in Fig.4, in which writing beam was 405nm laser beam and the reading beam was 1064 infrared laser beam. The concerns were on the wavelength effect of writing beam on the phase modulation. When writing beam was incident on the photoconductor of BSO crystal, the electric resistance of the BSO crystal was reduced proportionally to the applied writing beam intensity and effective voltage on the polymer network liquid crystal was thus reduce accordingly to the applied writing beam intensity which achieved optical addressing for phase modulation. The reduced resistance was mainly due to the occurrence of photo-generated carrier. The photo-generated carrier would be diffused or transferred by external applied

electric field, which influence the effective voltage applied on the polymer network liquid crystal. In the case of polymer network liquid crystal phase modulator, the response speed was so fast that the reorientation of liquid crystal director will

follow the change of effective applied voltage and influence the phase modulation of the proposed optically addressed phase only liquid crystal spatial light modulator. The dynamic response of ϖ phase change in the proposed phase only spatial light modulator based on low light scattering polymer network liquid crystal was shown in Fig.5. Kinds of writing beam with different wavelength was selected to study the effect of photoconduction on the optical addressing.

9242-67, Session PS

Remaining distortions, conditioned dimension of guide source

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Efficiency of the adaptive focusing of coherent laser beam of radiation is examined in a turbulent atmosphere. The calculation of distributing of averaged intensity of the field of coherent laser beam, focused in a turbulent media at the use of adaptive phase correction with the use of image of non-coherent source as a guide source is executed. We will mark that for effective work of wave-front cross-correlation sensor at track it is necessary to use maximally small in size, but contrasting display element. From the analysis of the theoretical expression easily to conclude that for vertical atmospheric paths, taking as a size of effective object of track the minimum settled object at a short exposure, such object can be counted practically by a point object. And he can be effectively used for the correction of phase. In an atmosphere on extensive paths strong aerosol scattering of image of guide source is possible and only extensive enough object, i.e., an object, having low spatial frequencies (LSF), will be visible contrastingly on a background other objects. It is related to that frequency-contrast characteristic of aerosol atmosphere has maximum in the area LSF and falls on spatial high-frequencies.

Conference 9243: SAR Image Analysis, Modeling, and Techniques

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9243-1, Session 1

Feasibility of COSMO-SkyMed constellation for radargrammetric DEM generation

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Space-borne SAR sensors have been used to measure ground elevations through InSAR techniques, which exploit the phase content of reliable acquisitions pairs. Thanks to the availability of high resolution SAR data, also Persistent Scatterer Interferometry (PSI) approaches have been recently exploited for height measurements on coherent targets. SAR radargrammetry is able to generate digital elevation models (DEMs) of the ground, exploiting the amplitude values of SAR image pairs, rather than their phase. This alternative technique is less accurate but more robust than interferometric methods, which can be strongly affected by coherence losses, atmospheric artefacts, and phase unwrapping errors.

The COSMO-SkyMed (CSK) constellation acquires data from its four SAR X-band satellites in several imaging modes, providing different spatial resolutions, polarizations, view angles and ground coverage. The present work investigates the potential of the CSK constellation for ground elevation measurement through SAR radargrammetry.

To this aim, we selected a test area around Parkfield (California, USA), where several CSK image pairs are available for both interferometric and radargrammetric processing. In particular, we selected 2 CSK spotlight image pairs acquired along ascending and descending orbits, respectively, in Same Side Viewing configuration, with spatial baselines around 350 m, and 1 day separation between the acquisitions of each pair. Furthermore, a dataset of 33 spotlight images, acquired along descending orbits, were selected to derive height measurements through both PSI and interferometric processing of 5 tandem-like pairs.

We first performed a feasibility analysis aimed at evaluating the impact of the errors in the geometrical parameters, as well as of the correlation level between the images, on the final DEM. It results that inaccurate knowledge of geometric parameters (orbits, baseline, look angle) has a negligible impact on the final height accuracy (than less 1%). The Cramer Rao limit was, instead, used to provide a figure of the height uncertainty as a function of the value of correlation between images computed at pixel level, figure involved in the computation of the pixel disparity, which is related to the ground elevation. In particular, a correlation value of 0.5 leads to an uncertainty of about 1 pixel on the estimated disparity.

Two DEMs were derived by processing the radargrammetric CSK pairs. According to the outcomes of the feasibility analysis, smoothing filtering and pixel selection were performed in order to guarantee nominal values of height accuracy within the HRTI Level 3 specifications (2÷4 m of relative vertical accuracy, 10 m of absolute vertical accuracy, and 12 m of spatial resolution). The products have a final planimetric resolution of 3 m.

In order to assess the accuracy of these radagrammetric DEMs, we used i) an SRTM DEM at 1 arcsec posting, fulfilling DTED-2 specifications, ii) the height values provided by the PSI processing of the spotlight time series with sub-metric precision, and iii) an interferometric DEM derived from the CSK tandem-like pairs fulfilling the HRTI Level 3 specifications.

Radargrammetric and interferometric DEMs were also fused to derive a refined product.

9243-2, Session 1

Advanced SAR simulator with multi-beam interferometric capabilities

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State of the art simulations are of great interest when designing a new instrument, studying the imaging mechanisms due to a given scenario or for inversion algorithm design as they allow to analyze and understand the effects of different instrument configurations and targets compositions. Moreover simulated data can be very useful to generate database of radar signature to replace real acquisition with collocated ground truth measurements, which can be very expensive or impractical.

In the framework of the studies about a new instruments devoted to the estimation of the ocean surface movements using Synthetic Aperture Radar along-track interferometry (SAR-ATI) an End-to-End simulator has been developed. The simulator, built in a high modular way to allow easy integration of different processing-features, deals with all the basic operations involved in an end to end scenario. This includes the computation of the position and velocity of the platform (airborne/spaceborne) and the geometric parameters defining the SAR scene, the surface definition, the backscattering computation, the atmospheric attenuation, the instrument configuration, and the simulation of the transmission/reception chains and the raw data. In addition, the simulator provides a inSAR processing suit and a sea surface movement retrieval module.

Up to four beams (each one composed by a monostatic and a bistatic channel) can be activated. Each channel provides raw data and SLC images with the possibility of choosing between Strip-map and Scansar modes. Moreover, the software offers the possibility of radiometric sensitivity analysis and error analysis due atmospheric disturbances (rain, water vapour), instrument-noise, interferogram phase-noise (temporal and spatial shift), platform velocity and attitude variations.

Each module can run independently of the others, thus the user can re-use outputs and only re-process the data of the modules addressing the desired modifications. The interaction with the simulator is ensured by OpenSF, a generic simulation framework environment that allows defining the main simulation parameters used throughout the simulation and to perturb them, allowing assessment of the science and engineering goals with respect to the mission requirements.

In this paper, the architecture and the capabilities of this simulator will be presented. Meaningful simulation examples will be shown, and the possibility to extend the simulation to different surfaces will be discussed.

9243-3, Session 1

Modeling atmospheric precipitation impact on synthetic aperture radar surface imagery at X and Ka bands

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Spaceborne synthetic aperture radars (SARs) operating at X-band and above allow observation of Earth surface at very high spatial resolution (of the order of meters) both in nightly and daily conditions. Moreover recent SAR systems being

fully-polarimetric allow the complete characterization of target scattering properties. Nowadays several spaceborne X-Band SAR systems are operative, for example COSMO-SkyMED constellation and TerraSAR-X/TanDEM-X, and plans are under development for spaceborne SAR operating at higher bands, such as Ku, Ka and W. Nevertheless even if the deployment of SARs constellations improves the reduced duty cycle of the instrument, X-SAR ground observations are limited by their sensitivity to atmospheric effects. Numerous works in the last years have assessed the sensitivity of spaceborne SARS operating at frequencies above C band. In particular atmospheric precipitations have demonstrated to condition SAR response echoes, both in amplitude and in phase. Also ground resolution results reduced to a few hundred meters due to the turbulent flow of hydrometeors during precipitations. The impact of precipitation on SAR slant-view imagery is due to a combination of surface and volumetric backscattering, coupled with path attenuation and with a significant dependence on frequency, polarization, spatial distribution of hydrometeors and their electromagnetic characterization. A valid aid to analyze and characterize SAR response to precipitation targets is represented by forward modeling, where a known scenario is used to simulate SAR response echoes. In this work a 3-D realistic polarimetric SAR numerical response model will be presented. The proposed model framework account for the SAR slant observing geometry and it is able to characterize the polarimetric SAR response echoes both in amplitude and phase. In particular in this work we have derived the Normalized Radar Cross Sections (NRCSs) and modulus and phase of the complex correlation coefficients. SAR frequency band is an input parameter: in this work we have considered both X and Ka bands to explore different atmospheric behaviors and possible future systems. The target scenario is simulated in a realistic way. The System for Atmospheric Modeling (SAM) high-resolution mesoscale model is used to extract the three-dimensional distribution of liquid and ice hydrometeors. Several hydrometeor classes are included in these simulations, in particular rain, snow, graupel and ice particles; their polarimetric signatures are derived by T-Matrix simulations. The scenario is completed by synthetic surface models considering both bare-soils, using the Semi-Empirical Model (SEM), and marine surfaces. The latter have been simulated by the SEAWIND2 two-scale model using the sea-surface wind vectors derived by SAM simulations over ocean. The proposed methodology has been applied in this work to perform a sensitivity analysis for the considered frequency bands and ground surfaces to different hydrometeor spatial distribution.

9243-4, Session 1

Intermittent Small Baseline Subset (ISBAS) monitoring of land covers unfavourable for conventional C-band InSAR: proof-of-concept for peatland environments in north Wales, UK

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Monitoring peatlands and other non-urban land covers with C-band Synthetic Aperture Radar Interferometry (InSAR) can be challenging due to temporal decorrelation. Presence of land with naturally-accumulated layers of dead plant material formed under waterlogged conditions does not favour the identification of coherent or persistent targets. Local topography can also add on further geometric constrains, in addition to issues of temporal phase stability. Such limitations have been already proven by the feasibility study recently undertaken at the British Geological Survey – BGS (Cigna et al. 2013), and in this paper these are dealt with by applying the newly developed Intermittent Small Baseline Subset (ISBAS) technique (Sowter et al. 2013). The latter is a small baseline, multi-looked, coherent target method, which considers the intermittent coherence of rural areas and allows denser coverage of land deformation estimates and more complete picture of the spatial patterns of ground motion to be achieved. We use the ISBAS processing solution to make the best out of SAR imagery for rural areas in North Wales, a land dominated by improved and acid grassland, heather, bog and coniferous woodland according to the UK Land Cover Map 2007. We employ 53 ERS-1/2 C-band SAR images acquired between 1993 and 2000, made available to BGS via the ESA Category-1 project id.13543. This research complemented the Glastir Monitoring & Evaluation Programme (Emmett et al. 2013), funded by the Welsh Government. Among its purposes, it aimed at achieving an InSAR proof-of-concept for peatlands, the conservation of which is nowadays one of the key environmental priorities at European level to mitigate effects of climate change. We processed the ERS-1/2 stack over a 4,460 km2 region of interest. With 200m perpendicular and 4years temporal baseline thresholds, a redundant network with 300 interferograms was generated. Only 4% of the scene revealed average coherence exceeding 0.25, whilst the remainder showed lower values, especially over peat, grass, forest and heather. ISBAS dramatically improved the average point density by a factor of 25 with respect to conventional SBAS. The greatest increase was achieved over coniferous woodland, which showed ISBAS/SBAS point density ratios above 300. Bog, acid grassland and dwarf shrub heath showed densities increasing to 150-160 points/km2 when using ISBAS. Despite the fact of relying only on a temporal subset of interferograms, the vast majority of the ISBAS points showed velocity standard deviations below 1.0-1.5 mm/yr, hence good quality of the estimated ground motion rates was preserved by using intermittently coherent targets.

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9243-5, Session 2

Preparing a new data set for earthquake damage detection in SAR imagery: the Christchurch example II

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In part I of this paper, the Christchurch, New Zealand, data set for earthquake damage detection was introduced and modifications to the 3d model were shown. With these modifications a realistic simulation of the model is made possible that can be used as a replacement for a pre-event SAR image which might not be available. This second part of the paper deals with the extraction of additional information from the 3d model in combination with the SAR imaging geometry and the SAR simulation process. Some examples how this information can be used to support the extraction of relevant damage information from the real post-event SAR image are given.

From the 3d model a height image of the scene is extracted. Including the SAR imaging geometry, a shadow and layover mask is created. Finally, the SAR simulation process provides information about the location of specular reflections of different bounce levels that can be used to create bounce masks in the SAR image geometry. While all of the algorithms used for the extraction of this information are rather well

known and have been published before, two examples are given how they can be put to use for the creation of realistic 3d models and for the change detection process.

For example, the height image of the scene is used as input for the creation of the shadow and layover mask. It also serves as height information for the accurate and consistent placement of objects in the scene. As an example, a workflow is introduced for the creation of realistic forested areas in 3d models. For this purpose, using the optical imagery available in Google® earth, geo-coded polygons are created within Google® earth defining the outline of the forest area. These are imported into a software module created at Fraunhofer IOSB that places trees inside the polygons at random locations. Additionally, the trees feature randomly created heights and orientations to account for the natural variety encountered in a forest. In order to get a consistent 3d model with the included trees, the height image extracted from the model is used for the correct placement of the trees on the ground.

The second example is the creation of bounce level masks, which aims at the extraction of dihedral and trihedral corner reflectors. For earthquake damage detection, especially the dihedral corner reflectors between ground and buildings are of interest. The workflow derived from the CohRaS®-SAR simulator developed at Fraunhofer IOSB is designed so that only those multi-bounce reflections that meet certain criteria are recorded. In this case, in its path through the scene the ray must at least touch the ground and a building once. Using a line detector on e.g. the double bounce mask and on a real SAR image, this information is transformed to the symbolic level. Based on this, it is planned to match the pre-event and post-event information on the symbolic level to use it as one input to the change detection algorithms.

9243-6, Session 2

Detecting sparse earthquake damages in high density urban settlements by VHR SAR data

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When an earthquake occurs, a rapid and accurate damage mapping of the hit urban area is important to manage the rescue team interventions. In this respect, satellite remote sensing data represent a very useful source of information, especially if the earthquake occurred in remote regions.

Seismic damage assessment based on Earth Observation data is a change detection problem which can be faced exploiting both optical and synthetic aperture radar (SAR) data. SAR data are very suitable for this kind of application mainly because SAR systems can provide images in almost any weather condition and independently of solar illumination.

Nowadays, very high resolution (VHR) SAR sensors, in principle, allow to produce damage maps at single-building scale. However, the detection of sparse and isolated damages in urban areas, by exploiting VHR SAR data is still a challenging task. Within urban settlements, the scattering mechanisms are complex and simple change detection analyses or classification procedures can hardly be performed.

In this work the 2009, L'Aquila (Italy), earthquake is considered as case study. Despite about 300 people were killed by the earthquake, few buildings were completely collapsed, and many others were heavily/partially damaged, resulting in a quite sparse damage distribution.

We analyzed pairs of VHR SAR data acquired by COSMO-SkyMed satellites, before and after the earthquake, both in SPOTLIGHT and STRIPMAP mode. Such analyses were performed to understand the SAR response of damaged structures surrounded by unaffected buildings, with the aim to identify possible strategies to map the damaged single buildings by using an automatic classification procedure. In this work, a classification approach based on a decision tree algorithm (DTA) was adopted. The preliminary analyses based on RGB images, generated by combining pre- and post-event backscattering images, allowed us to figure out how the damaged buildings are characterized in the SAR response. Usually a collapsed or heavily damaged structure results in two different effects on the post-event image: on one hand we can observe a decreased backscattering due to vanishing of the double bounce mechanisms, on the other hand we may have an increase of backscattering due to the presence of debris. Because of the SAR foreshortening, the first effect is misplaced with respect to the building footprint, when the double reflection originates from the upper part of the building. It appears towards the sensor at a distance that depend on the building height and on incidence angle. The second effect is located on the building footprints, or very close to it, as the debris lay on the surface. However, the presence of intact buildings or tall vegetation can mask such effects because, for instance, layover areas can superimpose when buildings have different heights. These outcomes have taken into account to set up the DTA. Decision rules and related thresholds were identified by statistically analyzing the values of backscattering and derived features.

This study point out that many pieces of information and discrimination rules must be exploited to obtain reliable results when dealing with non-extensive and sparse damage within a dense urban settlement.

9243-7, Session 2

Improved Characterization of Slow-Moving Landslides by means of Adaptive NL-InSAR Filtering

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InSAR and the Persistent Scatterer Interferometry (PSI) are well established techniques for monitoring urban and rural areas. Besides the large number of available SAR data in the past, the current and forthcoming space-borne SAR sensors offer the possibility of selecting the optimal acquisition configuration (wavelength, resolution, incidence angle, etc.) for each application. However, optimal data takes are not always possible and/or the processing area is difficult to analyse under an InSAR point of view. In such situations, additional and adaptive InSAR developments combined with other surveying techniques provide consistent solutions that meet the requirements of different application cases

This work presents an advanced InSAR processing adapted for an active slow deformation landslide in a mountainous area. The presentation will show the benefits of applying advanced and adaptive filtering strategies for improving the InSAR quality in highly de-correlated environments. The availability of Artificial Corner Reflectors over the area of interest enables to tune the filtering procedure and thus maximize the detection and exploitation of natural targets (bare soil, roads, rocks) as measurement points while preserving the phase characteristics over individual and punctual targets (building corners, poles). The new results will be evaluated in terms of final density and quality of measurement points that can be retrieved. The results will show that a very high density of measurements improves the detection of the deformation gradients and its perimeters resulting in a more accurate characterization of the landslide area.

The area of study is El Portalet, an active slow deformation landslide area in Central Spanish Pyrenees. During many years the slope of interest has been monitored with several surveying techniques like DGPS, extensometers, inclinometers, GB-SAR and InSAR jointly with an extensive geological interpretation.

Currently, in the frame of the FP7 Project LAMPRE, these surveying techniques have been complemented with 3D modelling, Artificial Corner Reflectors and a real-time automatic inclinometer. The technical developments of the

project show the potential of combining remote and in-situ measurements with advanced geomechanical models to better characterise and understand landslide behaviour. Some preliminary results of this combination of different technologies will be shown in the last part of our presentation.

9243-8, Session 2

Study of the impact of Ionosphere delay on the accuracy of SAR stereoscopic survey

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SAR satellites run in near-Earth space orbit that has a distance of hundreds of kilometers away from the ground, and its signal transmission link with the ground passes through the ionosphere. Therefore, Ionosphere has impacts on spaceborne SAR image including phase delay, distance and azimuth offset, Faraday rotation and so on. These impacts result in the decrease of imaging quality, thereby reducing the stereo positioning accuracy of SAR image. The current study on SAR image ionosphere effect is mainly concerned about the impact of ionosphere on SAR image quality, and the impact on SAR stereoscopic measurement accuracy has not been involved in the study. This paper is focused on the ionospheric delay which decreases the stereo positioning accuracy of L-band spaceborne SAR images. Utilizing L-band spaceborne SAR stereoscopic pair, simulation experiments is undertook. On the basis of analysis of experimental results, the relationship between the ionosphere delay and SAR stereo positioning accuracy has been given. The main work includes the following aspects:

1) The relevant researches about the impact of the ionosphere on SAR performance is summarized, further, the SAR image ionosphere phase delay model is established. Using the model, the ionospheric delay of X, C, L-band SAR imaging were calculated . Seen from the results, the slant range error caused by the ionosphere is proportional to the square of the SAR wavelength, that is to say, ionosphere has little impact on the data of X,C band, but the impact on L,P land can not be igored.

2) The ray tracing method of calculating electronic integral total (STEC)along the helical path of electromagnetic waves is proposed. TEC is replaced by STEC to improve calculation accuracy of ionosphere phase delay.

3) Based on linear equations and a number of ground control points, distance - Doppler conformational model of SAR images is used to achieve stereoscopic measurement of experimental data. The responding three-dimensional coordinates of ground point can be calculated through homologous image point coordinates of SAR stereoscopic images.

4) Combining different ionosphere TEC distribution models with SAR images ionospheric phase delay model, simulation calculation of ionospheric effects on the original stereoscopic SAR image data is conducted, then SAR images affected is measured stereoscopically. By comparison, the relationship between TEC distribution models and stereo positioning accuracy of SAR images is analyzed .

The experimental result shows that uniformly distributed TEC in the imaging field has no apparent effect on the 3D measurement accuracy since it can be calibrated and eliminated by utilizing the ground control point, whereas when TEC varies in position, it has a greater impact, with measurement errors up to tens of meters. Therefore, when high-resolution SAR executes the earth observation missions, the impact of the ionosphere needs to be considered and corrected effectively to ensure positioning accuracy.

9243-10, Session JS1

Target modelling for SAR image simulation

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Image simulation is important in the development and assessment of Automatic Target Detection and Recognition methods. The generation of synthetic imagery with known properties allows algorithm characteristics and performance to be considered in ideal circumstances, or on examples with particular artefacts or content, before being trialled on real-world imagery. For Synthetic Aperture Radar imagery there are a range of distributional models available for the simulation of clutter. These include probabilistic models which take account of the method by which the imagery was collected, along with empirical models which have been found to be a good match to certain types of land cover. In order to address target detection and recognition processes additional models are required which provide a good representation of the pixels of man-made target objects. Here the range of probabilistic models is much smaller, primarily consisting of the Swerling set of parameterised models and various recommendations regarding alternative empirical models. A number of extensions to the Swerling target model have been recommended in recent literature. This literature has discussed the motivation behind the model extensions and presents some theoretical results derived using them. However, two important aspects relating to the use of the extended Swerling models are yet to be discussed. The first relates to the fitting of the models to observed imagery of target objects; the second, to the synthesis of random fields with the prescribed distributions.

The extended Swerling model set consists of the gamma, the non-central gamma and the non-central gamma-gamma distributions. The first of these is identical to the standard Swerling model with the other distributions representing an increasing level of complexity and representational power. This paper examines the background of the extended Swerling model set and discusses the synthesis of random fields for these types. The paper also examines the fitting of models and parameters to data samples extracted from synthetic and real world imagery. For standard Swerling models semi-empirical parameterisation recommendations are available, and fitting is straightforward even where these suggestions are not followed. However, the extended Swerling models have additional parameters available to tune the fit to observations. The paper considers a number of methods for parameter fitting, based on the method of moments, numerical maximum likelihood and Markov-Chain Monte-Carlo techniques. Parameterisation of the extended Swerling models is shown to be challenging, firstly as a consequence of the increased number of parameters over that of the standard model and, secondly, because of the similarity between the models that make up this hierarchy. In simulation a large number of random fields are synthesised from each of the candidate distributions. Parameters are extracted and models selected using Bayes Information Criterion (BIC) for a range of sample sizes. Results show that for all but the largest samples the BIC is likely to select a simpler model from the hierarchy than that used to synthesise the random field. As large sample sizes are rarely available for the characterisation of target objects the use of these types of model in situations in which they must be fitted to data proves problematic.

9243-11, Session JS1

Non-destructive wavelet-based despeckling in SAR images

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The suggested wavelet-based despeckling method for multi-look SAR images does not use any thresholding to

avoid ringing artifacts, blurring, fusion of edges, etc. Instead, the logical operation of comparison is applied to wavelet coefficients which are presented in spatial oriented trees (SOTs) of wavelet decomposition calculated for one and the same region of the earth surface during SAR spacecraft flight. Fusion of SAR images is decided by keeping the smallest wavelet coefficients from different SOTs in high frequency subbands (details). The wavelet coefficients related to the low frequency subband (approximation) are processed by another special logical operation providing with a good smoothing.

It is because the described procedure depends on properties of the chosen wavelet basis then the library of wavelet bases is applied. The procedure is repeated for each wavelet basis. To select the best SOTs (and hence, the best wavelet basis) there is the special cost function which considers the SOTs as so-called coherent structures and shows which of wavelet bases brings the maximum entropy.

The results of computer modeling and comparison with few well-known despeckling procedures have shown the superb quality of the proposed method in the sense of different criteria as PSNR, SSIM, etc.

9243-12, Session JS2

Exploitation of a large COSMO-SkyMed interferometric dataset

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The new generation of high-resolution X-Band SAR sensors, such as the COSMO-SkyMed (CSK) constellation, allows acquiring data with spatial resolution reaching metric values. For PS targets, besides the displacement, also the elevation can be measured reaching metric accuracy. The main drawback is related to the availability of coherent targets on the area of interest. It was demonstrated that high resolution SAR sensors allow to increase the density of the measurable targets, making this approach to height measurement valuable. We already experimented the feasibility of using CSK data for ground elevation measurements by processing through the PSI algorithm SPINUA both spotlight and stripmap images acquired over Parkfield (California, USA). A standard deviation of about 0.6 m was measured, which is in line with indications coming from previous results proving the potential of PSI to provide ground elevation with sub-metric precision.

In this work we explored a dataset made by more than 100 images acquired by CSK constellation over the Port-au-Prince (Haiti) metropolitan and surrounding areas that were severely hit by the January 12th, 2010 earthquake. The images were acquired along ascending pass by all the four sensors of the constellation with a mean rate of 1 acquisition/week, in right-looking stripmap mode, HH polarization, and at a look angle of 20 deg.

This large CSK dataset was fully exploited by using SPINUA with the aim of: i) providing a displacement map of the area; ii) further assessing the use of CSK and PSI for ground elevation measurements; iii) exploring the CSK satellite orbital tube in terms of both precision and size.

In particular, significant subsidence phenomena were detected affecting river deltas and coastal areas of the Port-au-Prince and Carrefour region with maximum rate of movements around few cm/yr. PSI results also revealed the presence of very slow slope movements and local ground instabilities. This case study demonstrates that PSI represents a very good option for the assessments of ground instability in regions lacking in situ monitoring data.

Ground elevation was also measured on PS targets with resolution of 3x3 m2. The density of these measurable targets depends on the ground coverage, and reaches values higher than 4000 PS/km2 over urban areas, while it drops over vegetated areas or along slopes affected by layover and shadow. Heights values were compared with LIDAR data at 1x1 m2 of resolution collected over Haiti after the 2010 earthquake by the Center for Imaging Science at Rochester Institute of Technology, Kucera International, and ImageCat Inc.

Furthermore, by using geocoding procedures and the precise LIDAR data as reference, the orbital errors affecting CSK records were investigated in order to support the outcomes of recent works, which explain the limited geolocation accuracy of CSK products in terms of orbital and/or timing errors.

9243-13, Session JS2

Benefits of blind speckle decorrelation for InSAR processing

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Interferometric SAR (InSAR) exploits the phase differences of at least two complex-valued SAR images relevant to the same area acquired from slightly different orbit positions and/or at different times. The information derived is profitably used in application to topography estimation and environmental risk monitoring of ground deformation.

Angular decorrelation, induced by the spatial orbital diversity, and temporal decorrelation, induced by changes in the electromagnetic backscattering, are the major issues that affect the reliability of interferometric phase.

Point targets, and highly textured areas in general, play a major role, since their distribution of elementary scattering elements is relatively unchanged over time. On the contrary, vegetated areas may suffer from temporal decorrelation, which impairs interferometric phase measurements.

Spatial averaging (multilook) is usually exploited to counteract decorrelation effects affecting scattering mechanisms distributed over a large number of pixels. The interferometric coherence, evaluated through the (normalized) spatial averaging is a measure of the consistency of phase measurements at different passes.

The use of filtering window in the focusing stage typical of commercial single look complex (SLC) data products affects the interferometric multilook operation. The transfer function of the SAR acquisition systems, which includes focusing of the raw data, may introduce a spatial correlation of fully developed speckle, if frequency filtering, usually achieved through a Hamming window, aimed at improving the focusing of targets, is introduced in the deconvolution process that yields the SLC image from the raw data. Thus, the counterpart of getting well focused targets is that speckle turns out to be spatially correlated in the direction, range/azimuth or both, along which the frequency window was applied.

While well focused, and thus geometrically accurate, targets are highly desirable, speckle correlation may introduce an artificial increment of coherence in regions, mainly vegetated areas, in which a temporal decorrelation of radar echoes occurred. Since relatively high coherence values are a prerequisite for an accurate unwrapping of the phase field, such an increment may give rise to an erroneous detection of regions, in which the phase may be reliably unwrapped. Even if the frequency window may be enabled or disable on user's request, the two assets of carefully focused targets and uncorrelated speckle cannot be simultaneously achieved, so far.

In a recently published paper [1] some of the authors have investigated a viable strategy, requiring no a-priori knowledge of the SAR system and of the preliminary raw data processing, capable of "whitening" spatially correlated speckle. In fact correlated speckle is the main cause of the poor speckle filtering performances achieved by otherwise extremely advanced and sophisticated despeckling methods, when one-look amplitude/intensity images are processed for speckle reduction.

In this paper, a more extended group of authors have investigated whether the procedure developed as a preprocessing step before despeckling of detected images may be useful also in contexts where phase information is exploited. In a preliminary test set, an interferometric pair of COSMO-SkyMed StripMap images, featuring industrial buildings and vegetated areas, has been:

1) focused without Hamming window, starting from raw data;

2) focused with Hamming window, starting from raw data;

3) pre-processed by [1], starting from data at point 2).

Then, coherence maps and interferograms have been calculated for the three cases. In case 1) coherence is low on vegetation and also suffers from spreading of areas characterized by strong backscattering because of the presence of high sidelobes. In case 2) points targets and buildings in general are much more defined, thanks to the sidelobe suppression achieved by Hamming filtering, but the background coherence is abnormally increased due to the introduction of a spatial correlation. Case 3) is the most favorable because whitening operation carries out low coherence on vegetation and high coherence on buildings, where the effects of Hamming filtering are retained. A preliminary analysis of the phase field of the interferogram seems to reveal that case 3) should be expedited also in terms of phase unwrapping.

In conclusion, it is expected that the procedure in [1], devised as a blind pre-processing patch of SLC data, with the goal of a better despeckling, may be useful also for SAR interferometry, in which the tradeoff, dictated by the coefficient of the Hamming window, between the ideal situations of focused targets and uncorrelated speckle may be relaxed.

[1] A. Lapini, T. Bianchi, F. Argenti, L. Alparone “Blind speckle decorrelation for SAR image despeckling”, IEEE Trans. Geosci. Remote Sens., Vol. 52, No. 2, pp. 1044-1058, Feb. 2014.

9243-20, Session PS

Assessment of ground deformation at the Aquistore CO2 storage site in Saskatchewan (Canada) using satellite SAR interferometry

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Aquistore CO2 Storage Project is focused on the design, adaptation, and testing non-seismic monitoring techniques for measurement, and verification of CO2 storage, and integration data to determine subsurface fluid distributions, pressure changes and associated surface deformation. An array of remote sensing and engineering techniques is used in the study area including satellite Differential Interferometric Synthetic Aperture Radar (DInSAR), GPS, tiltmeters and piezometers.

A key difference between the Aquistore Project and other Carbon Capture and Storage (CCS) projects is that Aquistore is not associated with an oil reservoir. Many CCS projects focus on Enhanced Oil Recovery (EOR). EOR involves injecting CO2 into a depeleted oil field to increase production. Aquistore is not an EOR project. Aquistore is a dedicated storage site.

Aquistore is located in the Williston Basin. The targeted injection zones for the project are the Winnipeg and Deadwood formations. The Deadwood and Winnipeg formations are the deepest sedimentary units in the Williston Basin, and are below all oil production and potash-bearing formations in the region. They lay on granite and metamorphic Precambrian rocks which are dense and hard rocks that have no storage potential. The Deadwood and Winnipeg formations are simply sandstone formations that are more than 3000m deep, and are filled with very saline water. While these formations are defined as aquifers because they contain water, they do not contain drinkable water, or water that could be used for any agricultural purpose; this water is four to five times saltier than the ocean. These formations cover a vast area in west-central North America. In the area targeted they have no currently identified economic potential, other than as storage units for greenhouse gases.

Differential Interferometric Synthetic Aperture Radar is an advanced remote sensing technology for measuring ground deformation with sub-centimeter precision and high spatial resolution and coverage. To assess ground deformation at the Aquistore CO2 test site we applied various DInSAR processing chains as: stacking, Small BAseline Subset (SBAS), and Multidimensional Small Baseline Subset (MSBAS). The most advanced MSBAS method combines multi-angle multi-temporal SAR images into a single set of vertical and horizontal deformation time series improving their temporal resolution and precision. The C-band RADARSAT-2 data has been collected since May 2012 in order to map background deformation over the test site. The RADARSAT-2 data is acquired with the individual frequency of 24 days. We have collected data from five beams: ascending and descending geometries of Spotlight A with very high resolution of 1.6x0.8 m, ascending and descending geometries of Wide Ultra-Fine with moderate resolution of 1.6x2.8 m and descending geometry of Fine Quad-Pol with coarse resolution of 5.2x7.6 m, in range and azimuth directions. Such acquisition configuration allowed us to increase image frequency to 6 days on average in order to achieve nearly continuous temporal SAR coverage. Up to now, we have provided updated results based on over two hundred RADARSAT-2 images acquired from 2012 to 2014.

The processing of DInSAR data was performed with GAMMA software and consisted of the following steps: slave to master image coregistration and resampling; interferogram calculation and removal of the topographic phase reconstructed from very high resolution LIDAR DEM, adaptive filtering, phase unwrapping with

Minimum Cost Flow method, orbital error correction; and geocoding. The deformation time series were produced with SBAS and MSBAS techniques. For mitigating temporal de-correlation and for improving precision during the winter months when ground is covered by snow, we installed paired corner reflectors suitable for ascending and descending imaging.

Preliminary DInSAR analysis revealed slow ground deformation of few cm/year not related to CO2 injection but caused by various natural and anthropogenic processes as - snow melt, surface moisture oscillation, ground and surface water level changes and post-mining activity.

9243-32, Session PS

Repeat-pass interferometric coherence analysis for geosynchronous circular SAR

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1. Introduction

Circular SAR (CSAR) imaging on the geosynchronous orbit has significant potential advantages over the conventional low-Earth orbit (LEO) SAR, such as large coverage, short repeat period, high-resolution 3D imaging, and continuous surveillance of an interested area. Besides, repeat pass inrerferometry for GEOCSAR could also be carried out with images taken at 24 hours interval, and a 3D deformation measurement may be implemented. For SAR interferometric processing, quality of SAR interferograms depends on the decorrelation noise, such as images’ mis-coregistration, baseline decorrelation, temporal decorrelation. With CSAR imaging on the geosynchronous orbit, the altitude is very high, the atmospheric effect is severe and the high sidelobe is existed in the focused GEOCSAR signal. Thus, the characteristic of the various decorrelation sources of GEOCSAR interferometry will behave differently from the conventional interferometric SAR. This paper mainly analyzes the following sources of decorrelation: radar thermal noise, spatial baseline decorrelation, images’ misregistration and the atmospheric effects (including both troposphere and ionosphere).

2. Coherence analysis

2.1 Thermal noise decorrelation

The thermal noise decorrelation is mainly due to the signal to

noise ratio (SNR) or the noise equivalent sigma zero (NEσ0) of GEOCSAR. For the constant NEσ0, the thermal noise decorrelation mainly depends on the backscatter intensity.

2.2 Spatial baseline decorrelation and misregistration decorrelation

The spatial baseline decorrelation represents the possible changes of the scattering body during the two passes, and the misregistration decorrelation arises mainly from inaccurate image processing. For GEOCSAR, the synthetic aperture is curved and the spatial baseline may vary in the three dimensional (3D) space. Besides, the system response function of GEOCSAR is a Bessel function and the sidelobe is normally very high (PSLR is -7.9dB). Based on the imaging geometry and the signal processing, it is known that the spatial baseline decorrelation and coregistration decorrelation are related with the system response function, and thus such high sidelobe will severely impact the interferometric coherence. In this paper, the coherence loss function due to the high sidelobe of GEOCSAR is presented based on the relational model of system response function the coherence function.

2.3 Atmospheric effects

With long range (about 36000km) and long integration time (on the order of hours), the atmospheric effects on GEOCSAR performance is significant. The interferometric decorrelation due to the atmospheric effects mainly includes the temporal variation of the troposphere during the synthetic aperture and the spatial-temporal turbulence of the ionosphere. The temporal variation of the tropospheric refractive index will affect the GEOCSAR focusing and then impact the interferometric coherence. The ionospheric effect for GEOCSAR performance is severe for many factors. For interferometric decorrelation of GEOCSAR, we mainly discuss the decorrelation sources of the temporal variation of the ionospheric electron content during the synthetic aperture and the ionospheric spatial turbulence. The temporal variation and the spatial turbulence may cause image defocusing and severely degrade the interferometric coherence.

All the above decorrelation phenomena will be estimated and presented with the simulations, under the typical GEOCSAR system parameters.

9243-33, Session PS

Preparing a new data set for earthquake damage detection in SAR imagery: the Christchurch example I

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If natural disasters strike urban areas, the first emergency measures rely heavily on remote sensing data. SAR imagery, in particular, is highly suited, since it provides data regardless of weather and light conditions. There have been many different approaches addressing the subject of damage detection in high resolution SAR imagery, however, it still remains an open research issue. A huge drawback of approaches using straightforward pre- and post-event change detection algorithms is caused by the fact, that for areas not specifically at risk, high resolution data usually is provided only after a catastrophic event. This can be addressed by replacing the nonexistent pre-event image with a realistic SAR simulation, taking advantage of the ever increasing availability of 3d city models all over the world. The process of obtaining a simulated SAR image of an urban area, accurate enough for change detection, requires not only a capable simulator, but also a 3d model that first has to be adapted adequately.

In this paper we introduce a data set of Christchurch, New Zealand, with respect to the earthquake that caused devastating destructions in February 2011. Further, the preprocessing of this data set that is necessary to render it usable for the damage detection task is described in detail. The area is well suited for an exemplary change detection study, as it includes the common types of building sites, namely an inner city high-rise, a suburban, and an industrial area. The data set includes a high resolution TerraSAR-X image recorded the day after the earthquake and the corresponding reference information, e.g. optical signatures. Details are given about the 3d city model that was acquired, consisting of 2000 buildings and a triangle count of almost 400,000. While the buildings are modeled quite realistically, the ground only consists of a simple DEM. Even though the 3d model is highly detailed, experience shows that a SAR simulation based on a model like this cannot be accurate enough for a comparison with real imagery. The lack of differentiation regarding sections of differing radiometric characteristics, as for example vegetation and paved road, results in an unrealistically homogeneous simulation. Furthermore, the absence of vegetation, especially trees, leads to a missing concealment of specific buildings. Hence the induced intensities of the corresponding building corners are too high. Given the intention of a change detection effort involving both real and simulated SAR images, these are aspects that need to be addressed. For this reason, the 3d model was modified in several ways. First of all, the model was segmented by means of an open source GIS map to enable a reasonable material classification. Moreover, 3d models of trees were added to specific locations in the scene by means of a separate module, thus providing realistic concealment. To show the impact of these modifications on the simulated SAR signatures, simulated images for all stages of modification are shown and compared to the real TerraSAR-X image.

9243-34, Session PS

Polarimetric SAR tomography in the X-band by continuous wave multibaseline SAR tracks in a convex optimization approach

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SAR Tomography is the extension of the conventional interferometric radar signal processing, extended in the height dimension. In order to improve the vertical resolution with respect to the classical Fourier methods, high resolution approaches, based on the Convex Optimization (CVX), has been implemented. This methods recast in the Compressed Sensing (CS) framework that optimize tomographic smooth profiles via atomic decomposition, in order to obtain sparsity. The optimum solution has been estimated by Interior Point Methods (IPM). The problem for such kind of signal processing is that the tomographic phase information may be suppressed and only the optimized energy information is available. In this paper we propose a method in order to estimate an optimized spectra and phase information projecting each vector components of each tomographic resolution cell spanned in the real and the imaginary component. The tomographic solutions has been performed by processing multi-baseline SAR datasets, in a full polarimetric mode, acquired by a portable small Continuous Wave (CW) radar in the X band.

9243-35, Session PS

Experimental 3D SAR human target signature analysis

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Defence Research & Development Canada has been investigating 3-D through wall synthetic aperture radar (SAR) imaging from an experimental high resolution L-band through-wall SAR prototype. The side-looking radar is truck-mounted with data collected as the vehicle is driven past the front of a building of interest. Tools and algorithms for 3-D visualization are being developed to exploit the resulting imagery. The through-wall technology and data exploitation algorithms and tools have the capability to enhance situational awareness for military forces operating in an urban environment. Current

work involves analyzing signatures of human targets behind a wall and understanding the clutter and multipath signals that are present in a room of interest. In this paper, a comprehensive study of the characteristics of human target signatures in free space and behind two different wall structures is presented using 3-D SAR data. The aim of this investigation is to gain a better appreciation of the signatures of targets when placed behind different wall materials.

An analysis of the experimental human target signature in different poses is provided. Targets used in this investigation include a human in a standing position with arms resting at its side, a human standing with arms stretched out, a human kneeling, a human holding an AK47 in a vertical position, a human holding an AK47 in an angled position, a chair, and a human sitting in a chair, all at 10m in range with reference to the truck-mounted radar system at closest approach. Data are displayed as progressive top view 2-D slices. This provided a way to view, measure, and observe changes to the target signature from a top view perspective as the elevation was varied. In general, there is very close agreement between the measured physical dimensions of the targets and those obtained from the strong returns in the SAR imagery in free space. There is very close agreement between 2-D simulations found in the literature and the strong SAR image returns for the human targets. Most of the sources of the strong returns seen in the SAR images are explained, taking into consideration the measurements between different returns, and the location of the strong returns with respect to different physical features of each human target. Differences between human target signatures in free space and behind two different wall structures are presented.

Viewing of the SAR data as 2-D slices provides a qualitative means of discriminating between different target signatures. A more useful approach to discrimination would be to quantify these differences. The next phase of this investigation is to look at different quantitative features as potential discriminants. This study will also be enlarged to include more targets in different orientations as well as more exemplars of the human target in various positions in order to create a robust strategy for detection and classification of human targets. The research will continue the investigation of how the signatures of targets vary as they are moved behind different types of walls.

9243-37, Session PS

Feature of the displacement in applying the sub-pixel matching methodology to high-resolution TerraSAR-X images in the Great East Japan Earthquake 2011

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It is significant to acquire the information of the center and magnitude of the damages in the crucial disaster. The methodologies such as the change detection, and Differential SAR Interferometry (DInSAR) using satellite SAR data both pre- and post- event are developed, and several case studies shows the effectiveness of these methodologies. DInSAR is one of the most popular ways for estimating the displacement, however it has some restrictions, such as providing only one component of the displacement vector, saturating when the gradient of the displacement exceeds half a fringe per pixel. Pixel matching can resolve any displacement in affected region with large deformation.

Authors have studied the automatic sub-pixel matching methodologies for applying the one of the latest high-resolution SAR satellite, TerraSAR-X data, and evaluate how small displacement we can estimate the method in case using 20 pair of images with 1.25 m pixel spacing of Tokyo area in the Great East Japan Earthquake 2011, and revealed the accuracy about 0.2 m in X direction, and better than 0.1 m in y direction by comparing with the referenced GNSS observation data.

This study was aimed to show the accuracy and feature of the displacement depending on the selected targets using the three pair of TerraSAR-X images of Tohoku region acquired pre- and post- the earthquake in 2011. The automatic methodologies focused on the spatial texture around the targets, so there is some possibility that targets other than man-made objects are included. So the statistical analysis of the error of the displacement was conducted for the several sites for each target first, and we found the orientation of the man-made objects affected the errors quantitatively. We also focused on the coherence and the amplitude of the pixels for the analysis, and the relationships between these parameters and the accuracy were also shown. This paper shows the knowledge of the restrictions as well as the possibility applying the methodology to high-resolution SAR data.

9243-38, Session PS

Monitoring of surface deformation in open pit mine using DInSAR time-series: a case study in the N5W iron mine (Carajás, Brazil) using TerraSAR-X data

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This paper presents an investigation of displacement measurement using Differential SAR Interferometry Time-Series (DInSAR-TS) carried out in the N5W iron mine, Carajás Mineral Province (Brazilian Amazon region), using TSX-1 Strip Map data. N5W is one of the most productive open pit iron mine, with reserves (proven + probable) of 980.6 Million cubic meters@ 67.2% (December 2012). This mine has presented a historical of instability and surface monitoring measurements over sectors of the mine (pit walls) have been carried out based on ground based radar. During the period from March 2012 to April 2013 (dry and wet seasons), 32 TSX-1 differential interferometric pairs were used to measure deformation in the mining area. Due to complex topography of the site (deep excavations, high waste piles, etc.), a high resolution DEM was generated based on a stereo GeoEye-1 pair in order to decrease the topography phase error in the DInSAR analysis. Two complementary DInSAR approaches to measure surface displacements were used: (1) the simplest DInSAR configuration , as an early warning of the slope stability conditions and (2) DInSAR-TS. Despite the fact that a single pair results contain atmospheric and topographic phase artifacts and noise, it was possible to detect deformation in some interferometric pairs, covering pit benches, road ramps and waste piles. The time-series analysis was performed using the 32 interferometric pairs; one point located in a stable area was selected and taken as the zero-deformation phase value. The set of interferometric pairs was generated sequentially in time, but still presenting a set of small baseline, due to the better interferometric coherence presented in this configuration (the volumetric decorrelation is quite low due to the lack of vegetation). The time-series deformation was retrieved by using an extension of the SVD to obtain the Least-Square solution with a set of additional weighted constrain on the acceleration of the surface to control the smoothness of the time-series solutions, varying from no smoothing to a solutions that are essentially linear (Gamma RS software). The atmospheric phase artifacts were filtered in the space–time domain and the DEM height errors was estimated based on the normal baseline diversity. A corner reflector located in a stable area (around 1.2 Km from de reference point) was used to check the correct solution for this location. A highest deformation sector was detected over the waste pile (deformation rate = -486.5 mm/year), which is normally expected for this manmade structure. High deformation was also detected along benches and ramps on the SW sector of the mine (deformation rate = -255.7 mm/year), which was associated with surface movement evidences (fractures on bench walls, cracks on bench surfaces and road ramps), and in situ measurements using ground based radar. Two factors

contribute to this overall instability: deep excavation on low quality geomechanical ore/rock masses and a structural control given by NW-SE trending shear zone and EW trending fault system. The DInSAR time-series investigation showed good results for monitoring surface displacement in the N5W mine, which is located in a rain forest environment, providing very useful information about the ground movement for alarm, planning and risks assessment.

9243-39, Session PS

Imaging of downward-looking linear array SAR using three-dimensional spatial smoothing MUSIC algorithm

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In contrast to conventional side-looking SAR, downward-looking SAR (DL SAR) overcomes the restrictions of shading and layover, and it thus can acquire the whole information of the scene. However, the problem of DL SAR is the blind spot beneath the platform and the left/right ambiguity in cross-track direction, which can be resolved by beamforming operation with an uniform linear array of antenna elements distributed along cross-track direction instead of a single antenna element. Therefore, DL SAR with linear array is able to map a directly overflown scene into a high resolution three-dimensional image. Limited by the length of linear array, the resolution of cross-track direction is much lower than that of the range and azimuth direction. Traditional beamforming menthod using on ARTINO and DRIVE systems is based on FFT algorithm, which is restricted to Rayleigh limit.

Traditional MUSIC algorithm can be used to realize super-resolution spectral estimation in the cross-track direction. However, two drawbacks need to be taken into account. Firstly, target scattered power is not denoted by spectral peak of MUSIC algorithm. Secondly, scattering centers are always correlated in real SAR system, which results in the estimated covariance matrix be singular. Therefore, based on the imaging geometry of DL SAR with sparse MIMO linear array, the mathematic model of the receiving signal is firstly deduced as the product of the complex envelope matrix and the steering matrix.

To overcome the first drawback, the backscattering information of targets is estimated by the least square (LS) algorithm in this paper. To overcome the second drawback, we propose a new three-dimensional spatial smoothing method to restore the singular covariance matrix to a full-rank one, which is divided into a set of orthogonal three-dimensional subspaces. The estimated covariance matrix of signal is modified as the average of estimated covariance matrixes of all subspaces. Finally, according to the eigen-decompose of the estimated covariance matrix, the obtained eigenvector can be divided into two orthogonal subspaces, which named the signal subspace and the noise subspace. As a result, the location of each scatter center can be estimated by searching the maximum value of estimated angle spectrum. In addition, imaging performances are also presented in this paper. For a single target, the mainbeam width in the static antenna characteristics is discussed, which is inverse proportion to the ratio of antenna spacing and wavelength. For correlated multiple targets, the resolution of the MUSIC noise angle spectrum is quartic related to the angle difference, the ratio of antenna spacing and the wavelength.

At the end of this paper, the simulations of three-dimensional spatial smoothing MUSIC algorithm based on a single target or correlated multiple targets are realized. Compared with the traditional FFT algorithm, the simulation results of three-dimensional spatial smoothing MUSIC algorithm achieve higher cross-track resolution. Then, we simulate the cross-track resolution of three-dimensional spatial smoothing MUSIC algorithm with different ratios of antenna spacing and wavelength. Obviously, the cross-track resolution becomes higher with the increase of the ratio. Nevertheless, when the antenna spacing exceeds half of the wavelength, ambiguities appear in the spatial spectrum.

9243-40, Session PS

Ambiguities analysis in SAR tomography

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Synthetic Aperture Radar tomography (TomoSAR) has been widely studied to extract the three or higher dimension information of the forest area and the urban area. Several estimators for scatters number estimation and spectrum inversion have been developed for this application.

However, ambiguity problem in the spectrum may occur in the TomoSAR result which lead the inversion inaccuracy. In this paper, we investigate the ambiguity problems by mathematic derivation and simulation. Focus on each ambiguity, the corresponding solution is proposed.

Results shows that the ambiguities mainly come from two reasons: the non-full rank situation of the mapping matrix, and the coherence relationship between different scatters on the ground. The former one is due to the spatial contribution of the multi baselines. When one row in the mapping matrix is the linear combination of the others, the rank is not full so that to make the signals on two elevation the same. Considering the elevation range in TomoSAR, the first order ambiguity is the major. By mathematic derivation, it is proved that when the baselines set have common divisor, this ambiguity are the highest. The latter one is due to the coherence between different scatters on the ground. Since one SAR sensor only transmit and receive signals in the single frequency range, backscattering microwave may have the common frequency disturbance (CFD). In the TomoSAR model, the CFD phenomenon appear as the coherence characteristic. When considering the coherence characteristic of the scatters, the factors of the elevation vector are constitute from the same basic signal, which will make the signal subspace dimension in the covariance matrix less than the real backscattering scatters number. In other words, the signal subspace is leaked to the noise subspace in this situation so that to make the inversion result noisy. Considering the important position of the covariance matrix of the TomoSAR, this problem cannot be ignored.

To overcome the ambiguities problem, the corresponding methods are strongly advised when processing the TomoSAR. The ambiguities from the mapping matrix lead the reconsideration of the master image choice since the baseline set effect it deeply. A de-coherence method is necessary facing to the second ambiguity. In [4], it is proved that if the array is splited into several sub-array, the mix phenomenon between the signal subspace and the noise subspace in the covariance matrix is solve.

To prove the influence of the two ambiguities and the efficiency of the corresponding methods, a set of Radarsat-2 images are used. By switching the master image and using the de-coherence method, the inversion spectrum can be greatly improved.

9243-41, Session PS

Ship surveillance with Radarsat-2 ScanSAR

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The advantage of using scanning synthetic aperture radar (ScanSAR) image is not only its feature of all-weather and all-days, but also its huge covering swath with acceptable resolution. Ship detection is one of these special issues since its demand on high efficiency and accuracy. Radarsat-2, as the running advanced satellite with mature business model, is popular in SAR oceanographic application in these years.

In this paper, the application of Radarsat-2 ScanSAR on ship detection is presented. Different model of Radarsat-2 ScanSAR including the narrow and wide beaming as well as different

polarization of single polarization and dual polarization are used to give a whole performance for ship detection.

The overview of the flowchart is presented including four steps: (1) the sea split with geocoding masking, (2) the preprocessing step of ScanSAR normalization, (3) target detection in normalized images with improved constant false alarm (CFAR) method, and (4) ship clarified with low resolution. After the geocoding masking for the land-sea split, a new ScanSAR normalization method is used to solve the problem of backscattering energy unbalance along the range direction which is caused by the significant change of the incidence angle from near range to far in ScanSAR image. This method is designed without parameter estimation in polynomial fitting to ensure that the balance effect is stable. Ships are detected by the constant false rate (CFAR) since CFAR is one of the most stable detectors. A validation of the best fit distribution for the normalized image is processed including the Gaussian distribution, Log-Gaussian distribution, Weibull distribution, Gamma distribution and K distribution. Results show that the gamma distribution is the best fit in any model of Radatsat-2 ScanSAR images. Kernel density algorithm is used to filter the left strong noise from the background sea surface. The clarification is the necessary step for any ship detector since some other objects may appear as the ships. In this paper, we collect the positions of the oil-gas well, lighthouse in the image for feature clarification. The ambiguities of ships and land, and the small islands without signed in the geocoding map are also analyzed.

This paper presents the detection results for all the ScanSAR model of Radarsat-2 to give the effect of resolution, polarization, the number of swaths and other influence factor for each step of the ship detection algorithm. Experiments show that the narrow and wide beaming model make little difference, and the HV polarization is preferred. Moreover, the improved method of ScanSAR normalization, the ship detection and the clarification are validated from these images that prove the availability and efficiency.

9243-42, Session PS

Deformation monitoring in the Metro Manila using ALOS/PALSAR

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Excessive pumping of groundwater in the Metro Manila district, the Philippines, has occurred huge land subsidence. The purpose of this study is to investigate the distribution of spatial and temporal change on the earth surface in this area. We measured long-term ground subsidence by InSAR using JERS-1/SAR, ENVISAT/ASAR, Fine-beam and ScanSAR mode of ALOS/PALSAR data. As a result, we detected apparent subsidence and uplift patterns at eight locations. They have been found to correlate with up-down motion of groundwater level. The largest amount of ground subsidence was measured approximately 540 mm over 6 years (90mm/year).

On the other hand, some of deformations detected by the analysis were extended in parallel to the West Valley fault. The Republic of the Philippines lies across the boundary between the Eurasian plate and the Philippine Sea plate, an area ridden with active faults and frequent earthquakes. The Valley fault, running from north to south along the eastern edge of the Manila metropolitan, is a right-lateral active fault with two to four activities recorded over the past 1400 years; the estimated recurrence cycle translates to 200 to 400 years. According to recent studies, the last activity of the fault took place on August 19, 1658. In consideration of the estimated recurrence cycle, the region now faces a high risk of a devastating earthquake with a magnitude of 7 or higher.

Creep deformation along the southern part of the fault has produced some cracks to buildings and vertical displacement to road pavements in a north-south or northeast-southwest direction. There are extracted a displacement which the east side of the fault had moved down. This trend is in accordance with the results of leveling survey and topography, the tectonic movement is considered to be contributing the detected ground deformation. Because most of active faults are locked at the surface, strain has been accumulated over a long period and therefore causes a large scale earthquake. In contrast, the creep fault normally releases strain throughout the seismogenic layer and never generates a large earthquake. In some cases, however, a fault creep appears to happen within a shallow depth at a slower rate than the overall slip rate and produces moderate-to-large scale earthquake. Hence, the understanding and monitoring of the rate and the extent of fault behaviors are quite important to an assessment of a seismic hazard.

According to our data analysis, some of the land deformations are independent of the groundwater levels in the surrounding of the Valley fault. The difference in measurement times may partially explain this discrepancy, but we cannot deny the possibility that it resulted from creep deformation around the Valley fault. The spatial geometry of the surface deformation runs in parallel with the fault, and sites in the eastern part of the Valley fault stopped subsiding and began moving upward in around 2007.

9243-43, Session PS

High resolution image formation method based on the realistic spaceborne SAR modeling and simulation

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In studying image formation methods of the spaceborne synthetic aperture radar (SAR), we utilize its modeling and simulation (M&S) to generate its realistic simulated rawdata. Especially, for the spaceborne spotlight SAR, we perform M&S that reflects its real characteristics, and get rawdata that are almost identical to one acquired by the real SAR sensor.

Particularly, operations of the spaceborne spotlight SAR are simulated based on models of its dynamics and geometry related to timeline, orbital state vector, antenna beam pattern, azimuth beam steering, and etc. In addition, the target observation of it is modeled as evaluating observation angles related to point targets within the acquisition time. Finally, based on the received echo signal model, rawdata are simulated for point targets taking into account its real operation.

For the high resolution SAR image formation, simulated rawdata are focused with the extended chirp scaling algorithm. Especially, its range cell migration (RCM) factor is the key one for the exact range cell migration correction. In order to do it accurately, the Doppler frequency and the effective velocity have to be calculated correctly for all range sample bins. For precise processing, we suggest the method to analyze them using orbital state vectors and scene coordinates based on our two-way slant range model.

In experiments, system parameters and imaging scenarios to simulate rawdata acquisition of the spaceborne spotlight SAR system are defined. The processing results for realistic simulated rawdata of it are presented to evaluate the performance and the effectiveness of proposed methods. Its results show that suggested methods are applicable to form the high resolution spaceborne SAR image.

9243-44, Session PS

The COSMO-SkyMed support to earthquake events

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The frequency and impact of natural disasters worldwide is constantly highlighting the need for quick and appropriate

decisions from civil security and emergency responders, always more and more supported by the increasing availability of higher resolution, better accuracy, better revisit and response time and quicker-and-easier ordering and delivery of data, products and services. During the last decade the space sector has been challenged to reach operational excellence in this highly demanding field of application. With COSMO-SkyMed Italy has offered, and still offers today, an efficient response to actual needs of environment management during a considerably high number of real emergency events, such as earthquakes.

COSMO-SkyMed (Constellation of Small Satellites for Mediterranean basin observation) is the largest Italian investment of the Italian Space Agency (ASI) in Space Systems for Earth Observation. The Program is completely commissioned and funded by the Italian Government, mainly through the Italian Ministry of Research (MIUR) and the Ministry of Defense (MoD). It is a Dual-Use (Civilian and Defense) end-to-end Earth Observation System aimed at establishing a global service supplying provision of data, products and services compliant with well-established international standards and relevant to a wide range of applications, such as Risk Management, Scientific and Commercial Applications and Defense Applications.

The system consists of a constellation of four LEO mid-sized satellites, each equipped with a multi mode high-resolution SAR operating at X-band. The complete constellation has been deployed in orbit between 2007 and 2010.

From the space infrastructure perspective, the Italian COSMO-SkyMed SAR constellation is a typical example of a satellite system designed, developed and operated to support Emergency Management operations worldwide. The Italian COSMO-SkyMed constellation is providing a significant contribution to this goal providing timely and accurate radar images used in a wide variety of applications such as earthquake damage assessment.

Synthetic Aperture Radar (SAR) instruments operating in X-band like COSMO-SkyMed have demonstrated in several operational occasions their utility to support emergency management applications. In particular SAR application in case of earthquakes is related to the capability of the sensor to detect changes occurred in an area based on both SAR amplitude and SAR phase joint analysis of pre and post event SAR images. Therefore SAR satellites can help to precisely measure deformation of the Earth's surface following an earthquake and to support related seismological analyses.

COSMO-SkyMed satellites are very suitable for natural disaster monitoring, because they can acquire high quality images with very high resolution. As a matter of fact, COSMO-SkyMed has the unique capability to collect multiple images daily over any area worldwide thanks to its four satellites constellation. The results coming from the utilization of the four operative satellites reveal the significant achievement of the X-band SAR and the importance of fast response time especially in occasion of seismic events.

In this paper the analysis and results related to the application of COSMO-SkyMed data supporting emergency response operations in case of earthquakes as well as the description of some real use cases occurred in the last years will be presented.

9243-45, Session PS

MetaSensing's FastGBSAR: ground based radar for deformation monitoring

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The continuous monitoring of ground deformation and structural movement has become an important task in engineering. MetaSensing introduces a novel sensor system, the Fast Ground Based Synthetic Aperture Radar (FastGBSAR), based on innovative technologies that have already been successfully applied to airborne SAR applications. The FastGBSAR allows the remote sensing of deformations of a slope or infrastructure from up to a distance of 4 km.

The FastGBSAR can be setup in two different configurations: in Real Aperture Radar (RAR) mode it is capable of accurately measuring displacements along a linear range profile, ideal for monitoring vibrations of structures like bridges and towers (displacement accuracy up to 0.01 mm). Modal parameters can be determined within half an hour. Alternatively, in Synthetic Aperture Radar (SAR) configuration it produces two-dimensional displacement images with an acquisition time of less than 5 seconds, ideal for monitoring areal structures like dams, landslides and open pit mines (displacement accuracy up to 0.1 mm).

The MetaSensing FastGBSAR is the first ground based SAR instrument on the market able to produce two-dimensional deformation maps with this high acquisition rate. By that, deformation time series with a high temporal and spatial resolution can be generated, giving detailed information useful to determine the deformation mechanisms involved and eventually to predict an incoming failure.

The system is fully portable and can be quickly installed on bedrock or a basement. The data acquisition and processing can be fully automated leading to a low effort in instrument operation and maintenance. Due to the short acquisition time of FastGBSAR, the coherence between two acquisitions is very high and the phase unwrapping is simplified enormously. This yields a high density of resolution cells with good quality and high reliability of the acquired deformations. The deformation maps can directly be used as input into an Early Warning system, to determine the state and danger of a slope or structure.

In this paper, the technical principles of the instrument are described and case studies of different monitoring tasks are presented.

9243-46, Session PS

Prediction of Water Quality Parameters from SAR Images by Using Multivariate and Texture Analysis Models

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Remote sensing is one of the most important tools for monitoring and assisting to estimate and predict Water Quality parameters (WQPs). The traditional methods used for monitoring pollutants are generally relied on optical images. In this paper, we present a new approach based on the Synthetic Aperture Radar (SAR) images used to map and estimate the WQPs. To achieve this estimation quality, the texture analysis is exploited to improve the regression models. These models are established and developed to estimate six common concerned water quality parameters (PH, concentrations of Biochemical Oxygen Demand (BOD),and Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Salts (TDS) and Phosphate (PO4)) from texture parameters extracted from Terra SAR-X data. In this purpose, the Gray Level Co-occurrence Matrix (GLCM) is used to estimate several regression models using six texture parameters such as contrast, correlation, energy, homogeneity, entropy and variance.

For each predicted model, an accuracy value is computed from the probability value given by the regression analysis model of each parameter. Then, on all predictive models, the forward computations have been carried out to find the strongest R-square adjusted value. In order to validate our approach, we have used tow dataset of water region for training and test process. The training dataset is used to compute and estimate the proposed predictive model. To evaluate and validate the proposed model, we applied it on the training set. In the last stage, we used the fuzzy K-means clustering to generalize the water quality estimation on the whole of water region extracted from segmented Terra SAR-X image. Also, the obtained results showed that there are a good statistical correlation between the in situ water quality and Terra SAR-X data, and also demonstrated that the integration between in

situ parameters, the results obtained from SAR images and characteristics obtained by texture technique are able to monitor and predicate the distribution of WQPs in large rivers with high accuracy.

At the conference we will present precisely the adopted methodology and discuss the obtained results.

9243-47, Session PS

Focusing of bistatic data

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In the last years a few methodologies have developed to focus Synthetic Aperture Radar (SAR) data acquired using a bistatic configuration. This configuration can provide SAR images bearing a richer information on the scene than that contained in monostatic SAR images. The change of paradigm from monostatic to bistatic SAR configurations would increase the rate of observations. In fact, in monostatic acquisitions, SAR data are gathered by the same radar antenna that is illuminating the scene. This means that an image can be delivered just when a given satellite is flying the area of interest. In contrast, in bistatic data acquisitions transmitting and receiving antennas are different. As a consequence, the receiving antenna can observe just the area of interest while a radar source on board of any satellite flying over the area can be used as a transmitting antenna. This means that in a given time interval more images can be acquired since many satellites can illuminate the area.

However, this change of paradigm from monostatic to bistatic requires studies about the properties of this SAR configuration. New focusing algorithms are needed to produce SAR images since the bistatic geometry is more complicated than monostatic one where the 3D geometry can be simplified to a 2D geometry. Existing algorithms, methodologies and techniques were developed for data acquired in the simple monostatic configuration and cannot directly be applied to focus data acquired using the bistatic paradigm.

The availability of first bistatic SAR datasets collected at FGAN, DLR and ONERA, using simple bistatic configurations, gave rise to studies on the issue of focusing bistatic SAR images. The different acquisition geometry makes impossible the use of traditional focusing approaches tailored for monostatic SAR configurations so requiring new focusing algorithms specifically designed for a general bistatic configuration. First studies on bistatic SAR focusing refer to simple bistatic configurations with the transmitter and receiver having the same velocities, following each other on the same track with some fixed offset or with a cross-track spatial baseline. Some approaches were based on the derivation of the point spread function or spectrum in bistatic configurations. Just a few works tried to tackle the problem of SAR focusing in general bistatic configurations.

In this work we present:

1) A state-of the-art of methodologies so far developed to focus bistatic data, emphasizing the approximations at their basis;

2) A software to generate bistatic SAR raw data in different bistatic configurations intended to be used as a means to assess performances of bistatic focusing algorithms;

3) A new closed-form algorithm for the focusing of bistatic data.

9243-48, Session PS

Intermittent SBAS (ISBAS) InSAR with COSMO-SkyMed X-band high resolution SAR data for landslide inventory mapping in Piana degli Albanesi (Italy)

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Ground motions in the area of Piana degli Albanesi (Italy) were analysed for landslide inventory mapping purposes by exploiting the newly developed Intermittent Small Baseline Subset (ISBAS) technique and using 38 ascending and 36 descending mode COSMO-SkyMed X-band Synthetic Aperture Radar (SAR) images in StripMap mode which were acquired between 2008 and 2011. The test area covers 90 km2, with only 2 km2 showing good potential for SAR Interferometry (InSAR) and Persistent Scatterers (PS) applications. Our Land Cover Suitability Map based on a pre-survey feasibility study reveals potential for more than 2,500 PS/km2 across the test site, mostly located across built-up areas and where man-made structures are present [refer to Cigna et al. (2013) for the feasibility methodological approach]. Landslide-affected slopes in this area are, however, concentrated across rural and semi-vegetated land covers, where X-band PS and InSAR are generally unlikely to succeed. By using the ISBAS approach we overcome land cover constraints for PS applications in non-urban land covers, by allowing intermittently coherent pixels to be considered during the analysis and extending the coverage of InSAR results to rural, woodland, grassland and agricultural terrains (Sowter et al. 2013). Our COSMO-SkyMed ISBAS results reveal that during 2008-2011 the southern and eastern sectors of the slopes surrounding the dam of Piana degli Albanesi artificial reservoir moved at Line-Of-Sight (LOS) rates between 1.5 and 5 mm/year on average, due to the presence of highly–fissured material in the area of Mt. Kumeta and Mt. Maganoce thrust fault. In the north-western sector, dip-slope strata are predisposing factors for 10 landslides, one of which inactive. Multi-temporal COSMO-SkyMed ISBAS results were combined with ancillary data, including geological, geomorphological and pre-existing landslide inventory maps, and on site surveys for an independent validation of landslide ground motion directions, state of activity and typology. The outcome of our analysis demonstrated the predominance of complex (slide and flow) to flow type landslides together with Deep-Seated Gravitational Slope Deformations (DSGSD) phenomena, the former linked to outcrops of marly and clayey lithologies and, the latter, to the superposition of brittle carbonaceous over ductile rocks. Our approach allowed us to efficiently update the landslides inventory map of the test area, and to support the forthcoming generation of landslide susceptibility and risk maps at new levels of spatial detail and temporal updating that were not previously achievable.

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9243-49, Session PS

Combined use of COSMO-SkyMed derived products and hydrodynamic models to produce physically-based maps of flood extent

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Floods are the most frequent weather disasters in the world and probably the most costly in terms of social and economic losses. They have a strong impact on infrastructures and health since the range of possible damages includes casualties, loss of housing and destruction of crops.

Presently, the most common approach for remotely sensing floods is the use of synthetic aperture radar (SAR) images. Key features of SAR data for inundation mapping are the synoptic view, the capability to operate even in cloudy conditions and during both day and night time and the sensitivity of the microwave radiation to water. The launch of a new generation of instruments, such as TerraSAR-X and COSMO-SkyMed (CSK) allows producing near real time flood maps having a spatial resolution in the order of 1-5 m. Moreover, the present (CSK) and upcoming (Sentinel-1) constellations permit the acquisition of radar data characterized by a short revisit time (in the order of some hours for CSK), so that the production of frequent inundation maps can be envisaged. Nonetheless, gaps might be present in the SAR-derived flood maps because of the limited area imaged by SAR: moreover, the detection of floodwater may be hampered by phenomena as layover or shadowing, or complicated by the presence of very dense vegetation or urban settlements. Hence the need to complement SAR-derived flood maps with the outputs of physical models.

Through physical models variables needed for the assessment of flood damage, such as water depths and flow directions, which cannot be directly derived from satellite remote sensing data, can be delivered to end users. In addition, the flood extent predictions of hydraulic models can be compared to SAR-derived inundation maps to calibrate the models, or to fill the aforementioned gaps that can be present in the SAR-derived maps. Finally, physical models allow for the construction of risk scenarios useful for emergency managers to take their decisions and for programming additional SAR acquisitions in order to observe the temporal evolution of the event (e.g. the water receding).

In this paper, the first outcomes of a study aiming at combining COSMO-SkyMed derived flood maps with hydrodynamic models are presented. The study is carried out within the framework of the EO-based CHange detection for Operational Flood Management (ECHO-FM) project, funded by the Italian Space Agency (ASI) as part of the research activities agreed in the cooperation between ASI and the Japan Aerospace Exploration Agency (JAXA). The flood that hit the region of Shkodër, in Albania, on January 2010, is considered as test case. The work focuses on the utility of a dense temporal series of SAR data, such as that available through CSK for this case study, used in combination with a hydrodynamic model to monitor over a long time (in the order of 3 weeks) the natural drainage of the Shkodër floodplain. It is shown that by matching the outputs of the model to SAR observations, the hydrodynamic inconsistencies in CSK estimates can be corrected.

9243-14, Session 3

Multitemporal soil moisture retrieval from radar data: preparation of SMAP data processing over Italy

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Remote sensing measurements present a direct sensitivity to volumetric Soil Moisture Content (SMC) at microwave bands, where SMC influences the soil electrical permittivity, and then they represent a very useful tool to monitor soil moisture at different spatial scale. Soil moisture maps obtained by Synthetic Aperture Radar (SAR) systems are characterized by high spatial resolution. However, the radar return is sensitive not only to soil moisture, but also to surface roughness and, in presence of vegetation, to biomass parameters. These effects make the retrieval process quite challenging. Nevertheless, assuming that the variations of soil roughness and vegetation occurs at longer temporal scales with respect to the soil moisture, and the observations are taken within a short revisit time, multitemporal algorithms may mitigate those problems and deliver frequent and more accurate soil moisture maps.

In this work we apply a multitemporal algorithm to retrieve soil moisture from radar data, originally developed for the C-band radar aboard of the Sentinel-1 satellite (Pierdicca et al., 2014). We plan to adapt the algorithm to the images provided by the SMAP (Soil Moisture Active and Passive) L-band radar at different polarizations, possibly integrating in the procedure other data, such as the normalized difference vegetation index NDVI supplied by optical sensors. Such approach consists of integrating a dense time series of radar backscatter measurements within a multitemporal inversion scheme based on the Bayesian Maximum A Priori (MAP) criterion. The estimator inverts a forward soil backscattering model relating the backscattering coefficient to the bare soil parameters (not only soil moisture, but also soil roughness); the MAP estimator maximizes the probability density function of the vector of soil parameters (soil moisture and roughness) conditioned to the measurement vector. The water cloud model and other models have been analysed to correct the vegetation effects at L-band. The study has been carried out by using the data available from the SMAP Validation EXperiment 12, a field campaign designed for providing data to simulate the SMAP measurements. Such experiment has been performed in an agricultural region of south of Winnipeg, Manitoba (Canada), exploiting a range of crop types, some permanent grasslands, wetlands and mixed forest cover. Several in-situ measurements were collected in about 55 agricultural fields, as biomass, soil moisture, roughness and leaf area index. They are public domain data available through the NASA SMAP portal. All the measurement sites within a field have been averaged and associated to the SAR mean retrievals in order to perform a per-field assessment of the inversion approach. The results of the experiment will be discussed and strength and weakness of the approach will be summarised in comparison to the actual algorithm foreseen for operational processing of SMAP data.

[1] N. Pierdicca, L. Pulvirenti, G. Pace: A Prototype Software Package to Retrieve Soil Moisture from Sentinel 1 Data by Using a Bayesian Multitemporal Algorithm, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 7, no. 1, pp., 153-166, Jan. 2014.

9243-15, Session 3

An overview of neural network applications for soil moisture retrieval from radar satellite sensors

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Frequent and spatially distributed measurements of soil moisture (SMC), at different spatial scales, are advisable for all applications related to the environmental disciplines, such as climatology, meteorology, hydrology and agriculture. Satellite sensors operating in the low part of microwave spectrum represent an important tool for this purpose, and their signals can be directly related to the moisture content of the observed surfaces, provided that all the contributions from soil and vegetation to the measured signal are properly accounted for.

Among the algorithms used for the retrieval of SMC from

microwave sensors (both active, such as Synthetic Aperture Radar-SAR, and passive, radiometers), the artificial neural networks (ANN) represent the best compromise between accuracy and computation speed. ANN based algorithms have been developed at IFAC, and adapted to several radar and radiometric satellite sensors, in order to generate SMC products at a resolution varying from hundreds of meters to tens of kilometers.

These algorithms, which are based on the ANN techniques for inverting theoretical and semi-empirical models - such as the Advanced Integral Equation model (AIEM), Oh model, and Radiative Transfer Theory (RTT, in the simplified form of the 'Water-Cloud' model) - have been adapted to the C-band acquisitions from SAR (Envisat/ASAR) and from real aperture radar (ASCAT) and to the X-band SAR acquisitions of Cosmo-SkyMed and TerraSAR-X. Moreover, a specific ANN algorithm has also been implemented for the L-band active and passive acquisitions of the incoming SMAP mission. The latter satellite will carry onboard simultaneously one radar and one radiometer operating at the same frequency, but with different spatial resolutions (3 and 40 km, respectively).

Large datasets of co-located satellite acquisitions and direct SMC measurements on several test sites located worldwide have been used along with simulations derived from forward electromagnetic models for setting up, training and validating these algorithms. An overall quality assessment of the obtained results in terms of accuracy and computational cost was carried out, and the main advantages and limitations for an operational use of these algorithms have been evaluated.

9243-16, Session 3

Estimation of surface soil moisture in alpine areas based on medium spatial resolution SAR time-series and upscaled in-situ measurements

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Soil moisture content (SMC) is a key element in the global cycles of water, energy, and carbon. Knowledge on the spatial and temporal distribution of this parameter is therefore essential for a number of hydrological applications as well as other geosciences like meteorology or climatology (Heathman et al., 2003). In the last few years there has been an increasing interest towards the estimation of SMC at finer scales (<1 km) using active microwave sensors like synthetic aperture radar (SAR) (Barret et al., 2009). High resolution data is necessary to represent the strong spatial variability in alpine terrain. Due to the complexity, so far, these areas have been considered only marginally in research and only pioneer studies can be found in the literature (Brocca et al., 2012; Bertoldi et al. 2013).

The goal of this study was to assess the applicability of medium resolution SAR time-series, in combination with in-situ point measurements and SVR, for the estimation of SMC. This is a preparatory study to establish a methodology for the retrieval of SMC with high spatial and temporal sampling by integrating data from different remote sensing sensors combined with ancillary data from different sources. One of the main challenges was the combination of SMC point measurements with satellite data. Due to the high spatial variability of soil moisture a direct linkage can be inappropriate.

Data used in this study were in-situ SMC measurements from fixed meteorological stations located in the emerging Long-Term Ecological Research (LTER) site Mazia Valley (Province of Bolzano, South Tyrol, Italy) and SAR data from the ASAR WS sensor (150 m spatial resolution), combined with several ancillary data. As a further reference modelled SMC from the hydrological model GEOtop (Endrizzi et al., 2013) was included.

The SMC estimation in this work is based on the approach introduced by Pasolli et al. (2011). This method utilises a statistical model, the so-called support vector regression (SVR) method, to describe the relationship between several input features and a target variable. To relate the point measurements with the satellite pixel footprint resolution, a spatial upscaling method was developed. After the training phase it is possible to use the model to estimate SMC at unknown points.

Even though only few spatially different reference points were available, good estimation accuracies were achieved by increasing the number of samples in the temporal domain. It was found that both temporal and spatial SMC patterns obtained from various data sources (ASAR WS, GEOtop and meteorological stations) show similar behaviours, which indicates the robustness of the retrieval algorithm combined with ASAR WS. Furthermore, it was possible to increase the absolute accuracy of the estimated SMC through spatial upscaling of the obtained in-situ data.

Introducing information on the temporal behaviour of the SAR signal proves to be a promising method to increase the confidence and accuracy of SMC estimations. Following steps were identified as critical for the retrieval process: the topographic correction and geocoding of SAR data, the calibration of the meteorological stations and the spatial upscaling.

9243-17, Session 3

Use of time series of SAR images in the estimation of wet snow cover in the Andes of Argentina and Chile

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This work is part of the project: "Use of space technology for monitoring snow, glaciers and high mountain meadows in the central Andes of Argentina and Chile" framed in a program named "Oportunity Announcement (AO)", carried out by CONAE for the mission of the satellites SAOCOM 1A and SAOCOM 1B which is scheduled to launch on November 20115.

The zone under study is located in fragile ecosystems and mountainous areas of the Andes (border zone between the Province of San Juan, Argentina, and the IV Region of Coquimbo, Chile), of arid climate, where snow precipitates in the headwaters of watershed and feeds the rivers of the region by melting, being this the only source of water for human use, productive and energetic activities, as well as for native flora and fauna.

The main objective of the project is Improve water distribution incorporating space technology for its application in the stream flow prediction models in rivers feeded by melting of snow at high mountains in Los Andes.

So far there are results of 18 images COSMO SkyMed (9 pairs of Asc. and Desc. modes), 3 images SPOT and 5 images Landsat 8, corresponding to the 2012 and 2013 hydrological cycles. At the moment are processing pairs of images from July 2012 to today.

At the moment, the main tasks performed through the Project, were:

- Analysis of various values for TR (threshold used to discriminate areas covered with snow from areas without snow).

- Determination of the surface of wet snow cover, discriminated by altitude.

- Validation and comparison the map of snow cover obtained with optical images (SPOT 5) in the same dates of those of SAR images.

- Multi-temporal analysis of wet SCA in the months of April, July and september 2012.

- Multi-temporal analysis of wet SCA in the months of April, May and June 2013 (snow accumulation period).

- To train professionals Argentine and Latin American institutions through workshops.

The conclusions are as follow:

• It is a great advantage the availability of both modes (ascending and descending) in each date, since wet SCA information is recovered in percentages of almost double that separately with images of each mode.

• The results give that the greater percentage of wet snow in the basin is located between 3,000 and 5,000 m over sea level.

• The validation of the thematic map of July gave the following results:

i) Accuracy of snow class in both confusion matrices (considering two thresholds -2dB and -2.5dB) gave high values, over 85%, while the cover without snow gave values significantly lower. This is due to the fact that this class is not homogeneous, it is a mixed of with snow. Here arises the idea of generating a third class: “mixture of snow and rocky outcrop”.

ii) The accuracy obtained with TR-2 is greater than that obtained with TR-2.5

iii) The percentages of snow cover surfaces obtained from the optical image are very close to those obtained from SAR images

The wet SCA images obtained with COSMO SkyMED images allow a realistic characterization of the Andean mountainous areas, since it is usually found a mix of accumulated snow cover with rocky outcrops, which indicates a shallow snow cover. Besides, radar images allow detecting snow in those shadow areas where the optical images lose information.

The wet snow was determined following the procedure designed by Nagler, T. & Rott, H. (2000). The Dr. Markus Heidinger, belonging to ENVEO dictated workshop training to the working group of our project in Argentina.

The project also includes the participation of water resource management institutions like Secretaria de Recursos Hidricos and also of academic institutions like the University of San Juan. The project benefit these institutions from incorporation of new methodologies advanced digital image processing and training of staff (researchers, lecturers, PhD Students and technicians).

This work is part of the project: “Use of space technology for monitoring snow, glaciers and high mountain meadows in the central Andes of Argentina and Chile” framed in a program named “Oportunity Announcement (AO)”, carried out by CONAE for the mission of the satellites SAOCOM 1A and SAOCOM 1B which is scheduled to launch on November 20115.

The zone under study is located in fragile ecosystems and mountainous areas of the Andes. CONAE, the argentine Space Agency, participates in the Project through the provision of satellite data to the users and, through this, contributes to ensure the continuity of the results of the project. Also, it provides training in digital image processing.

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9243-18, Session 4

Corner reflectors and multi-temporal SAR inteferometry for landslide monitoring

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The application of multi-temporal differential SAR interferometric analysis to slope instability monitoring poses challenges related to the complex kinematics of the phenomenon, as well as to the unfavourable settings of the area affected by landslides, often occurring on sites of limited extension, characterized by steep topography and variable vegetation cover.

New-generation SAR sensors, such as TerraSAR-X (TSX), and COSMO-SkyMed (CSK), thanks to their higher spatial resolution, make DInSAR applications very promising for monitoring single man-made structures (buildings, bridges, railways and highways) as well as areas with low density of coherent scatterers. Nevertheless, the application of Multi Temporal InSAR (MTInSAR) techniques still remains problematic or impossible in rural and mountainous areas.

This is the case, for instance, for the Municipality of Carlantino, in the Daunia (Puglia) region, Southern Italy. Both C-band medium resolution SAR data from ERS-1/2 and ENVISAT ESA satellites, and X-band high resolution SAR data from the TSX satellite, were processed through the Persistent Scatterer Interferometry (PSI) algorithm SPINUA. PS targets detected by both C- and X-band data correspond to urban structures or peri-urban walls and guard rails and, despite the higher spatial density of PS from TSX, which cover part of the top of the landslide (already stabilized), the main body is lacking coherent targets, due mainly to vegetation and variable land cover.

Artificial reflectors can be used in place of natural coherent scatterers to allow stability monitoring. The availability of high resolution X-band data makes this solution attractive, since artificial reflectors of limited size can be adopted thanks to both short wavelength and high resolution. A small CR size is also suitable to minimize curvature of the side panels, effects of wind, exposition to vandalism, and to allow easy transportation/deployment in harsh terrain conditions.

The present work describes the design and deployment of a corner reflector (CR) network over the Carlantino landslide test site, as well as the PSI processing results for SAR data acquired over the area.

To design the CR network, different factors were taken into account: the visibility of the CR by the satellite in terms of geometry and radiometry, the accessibility of the location on the ground, and the relative distance between CRs. In fact, for this site, as is often the case, in situ conditions hinder a deployment of CRs which fulfils all the requirements of a reliable geodetic network.

A dataset of 40 TSX stripmap images acquired between January 2010 and December 2013 was available for PSI processing. The 26 images acquired after the CR deployment were also processed based on double-difference analysis of DInSAR phase values on the CR pixels. The results are affected by atmospheric artifacts, due to sub-optimal network geometry and strong topographic relief of the site, which limits the detection sensitivity to large relative movements. Nevertheless, the CR-based measurements result useful to assess and monitor the stability of the slope area already subject to consolidation works.

9243-19, Session 4

Utilisation of the COSMO-Skymed Constellation for coherent and incoherent monitoring

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With the advancement of modern sensor technologies SAR imaging and interferometry became a highly regarded source of spatial information. Using multiple satellites, such as all four SAR-Satellites of the Cosmo Skymed Constellation an improved temporal sensitivity is gained. It allows tracking of dynamic phenomena, gathering information over extended areas in a short time frame, as well as reacting within a minimum response time and acquiring information at a very high acquisition rate. By utilisation of this capacity new opportunities for generating geo-data relevant for risk management or food and environmental security are opened up. Results of relevant investigations based on COSMO-Skymed high resolution SAR imaging will be discussed in detail.

i) Incoherent monitoring

The acquisition capacity of the 4-satellite constellation provides the basis to map and monitor episodic events with a high degree of flexibility and agility. This is essential i.e. for determination of flood events. In that case spatial information is gained in terms of the determination of flood extents, while essential temporal characteristics result from the temporal sampling of floods, i.e. monitoring flood duration and draw off. Especially targeting marine applications the provision of routing and tracking information is crucial. Ice tracking is of fundamental importance both for maritime navigation and oceanographic/climate modeling. Information generation requires a flexible and agile acquisition system together with an efficient processing.

ii) Coherent monitoring

Different from the case of episodic changes continuous phenomena can be coherently monitored in an interferometric acquisition scheme. The observation rate generally needs to be adapted to variations and dynamics of the phenomenon. This is essential for the detection of i.e. (accelerating) terrain deformation due to construction works, landslides or hydrogeological risks. Within few months an interferometric time series analysis is applicable for this purpose guaranteeing maximum precision and recording of non-linear motion.

Human activities, i.e. agricultural field cultivation or mining activities, are caused by changes of the surface geometry which are often neither visible in optical images nor in SAR-amplitudes. Their detection is essential for predicting potential effects in terms of food or environmental security. These changes appear as small scale distortions of the surface geometries detectable as decorrelation in the coherence of interferometric pairs of SAR acquisitions. The coherent change detection approach can be applied on a daily base using the COSMO Skymed Constellation therefore be used for a variety of applications in the risk and security domain.

iii) Applications

Practical results of relevant studies in the field of risk management applications will be presented. These applications address flood monitoring, ice tracking, geohazards and human caused risk potential. In terms of food security results from cultivation monitoring studies will be demonstrated as well as our findings from environmental security projects, where those kinds of information are integrated in inspectorate and cadastral systems tools.

9243-21, Session 4

Impact of focusing of ground-SAR data on the quality of interferometric SAR applications

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A ground-based SAR system is a stepped-frequency radar. The processing of ground-based, space and airborne SAR data relies on the same physical principles, as the focusing step ideally requires a two-dimensional space-variant correlation of the received echoes with the point scatterer response of the SAR system. However, it is worth noting that a GB-SAR system is characterized by a sub-optimal synthetic aperture, being such a sub-optimality function of the antenna footprint in the azimuth direction. An exact focusing method is that of the Frequency-Domain Back-Propagation algorithm (FDBA). This approach is supposed to be applied to a stepped-frequency continuous-wave (SF-CW) or a Multiple-Input Multiple-Output (MIMO) radar and consists in the coherent sum of the stepped frequency contributions at the different radar positions along the aperture, corrected for their phase delay. The computational load associated to this method is O(M N M’ N’) where (M, N) are the dimensions of the raw data matrix and (M’, N’) that of the focused image. As for the spaceborne case, a close-to exact focusing can be achieved by the wavenumber-domain algorithm. In this work we present a study of the impact of the focusing algorithm on interferometric SAR applications. Synthetic and real datasets will be used to assess the impact of focusing algorithm on interferometric phase dispersion and coherence values.

An experiment has been carried out to assess both the precision and accuracy of GBSAR displacement measurements. A corner reflector mounted on a micrometric screw has been used to acquire fourteen SAR images. A set of thirteen interferograms was generated by processing the each SAR image with the subsequent one. The micrometric screw was displaced of few millimetres in the direction of radar. The mean and dispersion of phase values in correspondence of corner reflectors were compared to those obtained by the know displacement of the micrometric crew.

Examples of real interferograms of landslides, dams and buildings will be also shown. The phase dispersion and coherence values found in the above interferograms for each focusing algorithm will be quantified.

9243-22, Session 4

An assessment of TanDEM-X GlobalDEM over rural and urban areas

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Digital Elevation Model (DEM) is a key input for the development of risk management systems. One main limitation of the current available DEM is the low level of resolution. DEMs such as STRM 90m or ASTER are globally available free of charge, but offer limited use, for example, to flood modelers in most geographic areas, either because of the lack of height information over water surfaces or the inability to distinguish critical urban infrastructure.

TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement), the first bistatic SAR can fulfil this gap. The mission objective is the generation of a consistent global digital elevation model with an unprecedented accuracy according to the HRTI-3 specifications. The mission opens a new era in risk assessment.

RASOR (Rapid Analysis and Spatialisation and Of Risk) is a response to the Call for proposals FP7-SPACE-2013-1, addressing topic SPA.2013.1.1-06 “Stimulating development of downstream services and service evolution”. The main objective of RASOR is the development of a platform to perform multi-hazard risk analysis to support the full cycle of disaster management, including targeted support to critical infrastructure monitoring and climate change impact assessment. One of the main innovations proposed in RASOR is the use of TanDEM-X GlobalDEM data. The GlobalDEM will be adapted to risk management applications, using it as a base layer to interrogate data sets and develop specific disaster scenarios.

In the framework of the Announcement of Opportunity XTI_LAND1554, the capability of TanDEM-X CoSSC data for DEM generation in vegetated areas has been investigated. The

DIAPASON processing chain has been successfully adapted to CoSSC data processing; preliminary promising results have been presented during the former TanDEM-X science meeting. The present study is a preliminary assessment of the GlobalDEM quality. This assessment will be done over a test site where a LiDAR DEM is available; this layer will be used as reference. DEM issued from the TanDEM-X first global coverage will be compared with the corresponding DEM generated with the DIAPASON processing chain from a CoSSC pair. Performances of the two DEMs will be evaluated over rural and urban areas and compared with the reference topographic map. Special emphasis will also be put over rivers and other continental water bodies. This analysis will also allow the validation of the updates done on the DIAPASON processing chain.

9243-36, Session 4

The PSIG chain: an approach to Persistent Scatterer Interferometry

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This paper describes a new analysis and processing Persistent Scatterer Interferometry approach implemented at the CTTC. Its key steps are a selection of PS candidates based on a phase similitude criteria and a 2+1D phase unwrapping algorithm. In addition to the deformation velocity map and the PS Time Series (TS), a quality index for each TS and other parameters related to the detection and correction of unwrapping errors is obtained. The PSIG chain has been successfully tested over urban and rural areas. The results of the full frame TerraSAR-X processing over Barcelona (Spain) using a stack of 28 StripMap images will be presented.

The PSIG chain starts from N images and M wrapped interferograms (M>>N) and the dispersion of amplitude (DA) and it involves three main processing blocks. The first block is the selection of the so-called PS cousin candidates (CPS) that must be homogeneously distributed over the area of interest. In the second block, the Atmospheric Phase Screen (APS) is removed from the M unwrapped interferograms by means of a set of spatial and temporal filters. In the third block, the final deformation measurements are estimated and a set of quality parameters over the estimations are presented. The main steps on each block are described in detail:

1) CPS selection. This block involves three main processing steps:

1.1. Candidate Cousin PS (CPS) selection. A set of PSs with phases characterized by a moderate spatial variation is sought, starting from at least one seed PS and searching for PSs with similar phase characteristics.

1.2. 2D phase unwrapping. The spatial phase unwrapping of the candidate CPS is performed by means of an implementation of the Minimum Cost Flow method (Costantini, 1998; Costantini et al., 1999).

1.3. Phase unwrapping consistency check. This step ensures the good performance of the phase unwrapping. It is based on Least Square estimation and an analysis of the residues between the unwrapped observations and the estimations. The final net of CPS is finally obtained.

2) APS estimation and removal. The APS is estimated over the CPS using a set of spatio-temporal filters (Ferretti et al., 2000 and 2001; Berardino et al., 2002; Mora et al., 2003) and it is removed from the M original unwrapped interferograms.

3) Deformation measurement estimation. It is performed in three processing steps:

3.1. Estimation of deformation velocity and RTE. The deformation velocity and RTE (and optionally, the thermal expansion component (Monserrat et al., 2011) are obtained from the M wrapped APS-free interferograms, using the method of the periodogram.

3.2. RTE removal. The RTE component is removed from the M wrapped APS-free interferograms. Optionally, the thermal expansion component can also be removed.

3.3. 2+1D phase unwrapping. A 2D spatial unwrapping is performed over the RTE and APS free interferograms. The final deformation phase time series, a quality index for each time series and other parameters related to the detection and correction of unwrapping errors are obtained on this last step.

9243-23, Session 5

Use of airborne polarimetric SAR, optical and elevation data for mapping and monitoring of salt marsh vegetation habitats

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Within the Copernicus programme there is much interest in the ability of remote sensing technology to deliver operational solutions to many areas of life including environmental management. Integrated Coastal Zone Management (ICZM) seeks to find a balance between human use and sustainable functioning of coastal zone ecosystems. Coupled with general interest in ecosystem services, this research explores methods for characterising coastal salt marsh zone habitats in terms of the environmental benefits and affordances they confer with the use of under-exploited Synthetic Aperture Radar (SAR) remote sensing techniques, thereby providing additional information in support of the management of coastal zones.

The research consists of examining the use of full polarimetric airborne S- and X-Band for habitat mapping of salt marsh areas, following common habitat classification schemes as National Vegetation Classification (NVC) or Habitat Directive Annex 1.

This is done on the basis of an airborne SAR data set which is acquired over the Llanrhidian salt marsh in Wales in July 2010 with the Astrium Airborne Demonstrator, as a precursor test system to the upcoming NovaSAR-S mission. This SAR data set provides an excellent opportunity to research the potential of high resolution fully polarimetric SAR for classification of salt marsh habitats, by characterising botanical and structural composition of specific salt marsh vegetation zones. SAR-derived variables, such as backscatter coefficient, band ratios and polarimetric decomposition parameters are extracted. These are combined with high-resolution optical and elevation variables to create a multi-source aggregate RS data set to perform supervised classifications for mapping of the main salt marsh vegetation habitats, as well as multivariate regression to analyse correlations between RS variables and vegetation parameters like cover, height and volume. Classifications are trained and validated with ecological field data. This presentation will focus on classification results from the airborne SAR data set, the use of polarimetric information and its added value for vegetation mapping.

Discussion:

This research has shown that SAR data can be used to identify salt marsh habitats and to support ICZM. Ongoing research is improving the applicability of satellite and airborne SAR sensors to a range of coastal zone problems and is exploring how the combination of a multi-sensor and multi-temporal SAR approach gives more insights into long-term dynamics of intertidal land cover and ecosystem functions. These are particularly important in intertidal habitat areas and for the ecosystem services they provide.

9243-25, Session 5

The monitoring of soil and vegetation parameters from COSMO-SkyMed data

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The capability of Cosmo-SkyMed SAR data in monitoring vegetation has been investigated in this paper. SAR data were collected on two agricultural areas in Italy from 2010 to 2012 at different dates during the vegetation cycle. X-band data have been compared to accurate ground truth measurements of soil and vegetation parameters carried out simultaneously to satellite passes.

Although X-band is not the best frequency for the monitoring of soil moisture, due to the scarce penetration power and the significant effect of surface roughness and vegetation on the radar signal, a clear correlation of the backscattering coefficient to soil moisture of bare and smooth soils was observed.

A significant sensitivity of backscatter to vegetation water content of agricultural crops was observed. However, the backscattering showed an opposite trend as vegetation grows for wheat and sunflower, which belong to two very different vegetation types, namely narrow-leaf and broad-leaf. Similar trends have already been pointed out at lower frequencies (i.e. C and L bands) for the same crop types.

In order to investigate the role of different parameters of soil and vegetation (e.g. surface roughness and moisture, plant density and height, dimensions of leaves, stem diameter, water content, etc.) on the backscatter behavior for these two different crop types, model simulations were performed by using a discrete element radiative transfer model for vegetation, whereas soil was modeled by using the AIEM (Advanced Integral Equation Model). A sensitivity analysis of the model was carried out varying the dimensions of soil and vegetation components within the range of parameters measured on ground during the experimental campaigns.

The model simulations were successively compared with experimental data of backscattering. The good agreement found between experimental and simulated data encouraged the follow-up of the research toward the implementation of an inversion algorithm which can be able to retrieve vegetation biomass from SAR data and from an operative point of view.

9243-26, Session 5

COSMO-SkyMed potentiality to identify crop-specific behavior and monitor phenological parameters

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In the last few years the amount of data available from satellite X-band SAR sensors have increased dramatically and, significant studies on the crop parameters monitoring have been published.

The aim of this study is twofold: first, to investigate the potentiality of the COSMO-SkyMed (CSK) X-band SAR system to identify plant structural changes of different crop species over an agricultural area and, second, its potentiality to estimate the Leaf Area Index (LAI), which is one of the key parameters characterizing the vegetation growth.

A unique dense time-series of COSMO-SkyMed imagery has been acquired over the Marchfeld region, in Austria (lat/long 48°14'23"N; 16°37'24"E) from June to November 2013. The scenes were acquired in alternating ascending and descending orbit configurations, at different incidence angles (20°, 30° and 50°), and in two different acquisitions modes, namely Stripmap PingPong dual-pol. mode (at VV-VH pol.,@~15 m ground res.), and Stripmap Himage single-pol. mode (HH, VV and VH pol., @~ 3m ground res.) for a total of seventy-two scenes.

A dataset consisting of nine optical images (6 Deimos-1 and 1 Landsat-8) were also acquired within a similar time span as for CSK acquisitions. LAI maps have been derived for the area and used to classify the crop species in the area and to investigate the relationship with the radar backscattering at X-band and the LAI. Daily precipitation data, recorded at two meteorological stations located near the test site, and ground truth information, provided by local farmers, were also used for the final analysis.

From the nine LAI maps data stack, a multi-temporal image classification was applied. Ten different crops have been classified namely carrots, potatos, alpha-alpha, corn, soybean, pea-green, winter-crops, sugar-beet, cucurbitaceae crops, summer crops. The analysis was carried out over many of the crop species present in the studied area and over several fields of the same crop type. An analysis of the backscattering temporal signature of the different crops calculated over largest fields (i.e. > 30 pixels) together with a correlation analysis of the backscattering vs. LAI will be shown both for the available Himage and PingPong time-series data.

From this preliminary analysis it can be concluded that:

• Only satellite system with an high revisit time can potentially catch different phenological changes of a crop cycle;

• Radar backscattering depends on the plant elements dimensions and spatial disposition;

• As it has been found in previous studies at frequencies other than X-band, backscattering is positively correlated with LAI for broad-leaves species, while it is negatively correlated for narrow leaves species;

• backscattering values are affected by strong rainy episodes and precipitations occurring during and before SAR acquisitions.

Future work will consist in acquiring for the 2014 season an even denser dataset of CSK images over the same area. An analysis of different empirical radar-based vegetation index, exploiting the data angular and polarimetric properties of the system will be carried out.

9243-28, Session 6

Soil moisture estimation using synergy of optical, SAR, and topographic data with Gaussian process regression

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In this work we address the synergy of optical, SAR and topographic data in soil moisture retrieval over an Alpine area. As estimation technique, we consider Gaussian Process Regression (GPR) [1]. The test area is located in the Mazia Valley, South Tyrol, Italy [2] where the main land types are meadows and pastures. Time series of SAR, optical, topographic and ancillary data (meteorological information and snow cover maps) acquired repetitively in 2010 were examined. We extracted backscattering coefficients and corresponding local incidence angle values from 89 ASAR WS acquisitions in VV polarization with 150 m resolution. All geometric distortions (shadowing, layover) were masked. Regarding optical data, we used both daily reflectances obtained from 7-band MOD09GA MODIS product reprojected to 500 m resolution, and daily 250 m resolution NDVI, interpolated from 16-day composite MOD13 of MODIS. Slope, elevation and aspect features were extracted from a 2.5 m LiDAR DEM and resampled to 10 m. A high-resolution (25 m) land-cover map of the Mazia valley was derived from ortho-photos, ground surveys, and visual interpretation [2]. Daily soil moisture measurements were collected in the three fixed climate stations (2 of them were located in meadows and 1 in pasture) at an altitude of 990 m, 1490 m and 1930 m, respectively. We used snow maps derived from the 250 m - resolution MODIS Bands 1 and 2 [3]-[4] to

mask the points covered by snow. GPR was implemented according to [1] and its accuracy was tested by employing the Leave-One-Out procedure, i.e. considering each sample in turn as a test instance, and with rmse and R2. After removing the points where some of the features were not available or masked, the total number of usable samples was of 110. The relative contribution of the different features involved was also tested. When using only daily reflectance, GPR provided a R2 of 0.33 and a rmse of 9.26 % Vol. When including the parameters issued from the DEM, GRP resulted in a R2 of 0.59 and a rmse of 7.88 % Vol. In both cases, MODIS Band 6 (1640 nm) and Band 7 (2130 nm), showed significantly higher relevance. Estimation of soil moisture from joint SAR and DEM data resulted in a R2 of 0.8 and a rmse of 6.05 % Vol. The best performance was obtained by adding MODIS band 6 to SAR and DEM features. The corresponding R2 was of 0.848, with a rmse of 5.4% Vol. Compared to the case when no optical data were considered, there was an increase of ca. 0.05 in R2 and a decrease in rmse of ca. 0.5 % Vol.

These results show that the joint use of NDVI and water absorption reflectance with SAR and topographic data improved the estimation of soil moisture in specific Alpine area and that GPR is an effective method for estimation. In the future, we plan on comparing the results with ongoing soil moisture estimations from backscatter radiative transfer model inversion and with simulations obtained from an hydrological model.

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9243-29, Session 6

Oil spill analysis by means of full polarimetric UAVSAR (L-band) and Radarsat-2 (C-band) products acquired during Deepwater Horizon Disaster

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Remote sensing provides a powerful tool for sea surface monitoring, permitting the observation of large areas at one time. SAR sensors, in particular, permit continuity of observation and analysis regardless of weather and light conditions. The new generation of instruments with polarimetric capabilities, high resolution, and short revisit time can provide a breakthrough in oil spill monitoring. The presence of an oil film on the sea surface damps the small waves due to the increased viscosity of the top layer and drastically reduces the measured backscattering energy, resulting in darker areas well detectable in SAR imagery. However, careful interpretation is required because dark areas can also be caused by low winds, currents, rain cell or natural slicks.

Because of the very low backscatter from slicks, the Noise Equivalent Sigma Zero (NESZ) is a primary sensor parameter to consider when using a sensor for slick classification. A new generation of quad-polarimetric satellite SAR sensors (ALOS-2, Radarsat Constellation, COSMO-SkyMed2, Radarsat-2) or airborne fully polarimetric SAR(Uninhabited Aerial Vehicle SAR, L-BAND, JPL-NASA) offer great opportunity of for this analysis. Of the existing sensors, the high resolution and very low Noise Equivalent Sigma Zero value of UAVSAR (-52db) and RADARSAT-2 (-31db) make them preferable for oil spill analysis compared to the last generation SAR sensors, coherent dual pol. TerraSAR-X (-19db) and multipolarization CosmoSkymed (-22db). It is possible to reliably measure changes in backscatter inside the radar-dark areas, making possible spill characterization, particularly through multi-polarization or polarimetric analysis.

Among the methods developed for polarimetric analysis, the Cloude-Pottier decomposition has gained great popularity. The most important advantage of this basis invariant technique is the capability of determining the scattering mechanism. The decomposition is based on the eigenvectoreigenvalue calculation from the coherence matrix, from which it is possible to extract parameters that describe the scattering mechanism of the target.

In this work, we investigate the potential of full polarimetric radar to discriminate oil on the sea surface from look-alike phenomena covering the full range of backscatter down to the values at the instrument noise floor. We do this by considering the different scattering mechanisms that occur for slicks and look-alikes and also by comparing their response to different frequency SARS, which have different penetration.

Making use of the unique opportunity to study a thick, spatially extensive slick that occurred during the DeepWater Horizon oil disaster in Gulf of Mexico, we investigate many acquisitions from different SAR sensors, in different bands, and with near-to-exact temporal overlap, which are supported by a large ground truth dataset collected during the spill. The latter two aspects are crucial in a dynamic environment such as the sea surface, in which the contributing effects of wind, currents, emulsification, spreading, and evaporation rapidly change the features of the sea surface under investigation.

By comparing quasi-simultaneous polarimetric acquisitions and exploiting the different penetration capabilities of the sensors, we show that we can retrieve information about the oil properties, in particular an index of thickness, from SAR if the backscatter is sufficiently above the instrument noise floor.

9243-30, Session 6

Wake-based ship route estimation in high-resolution SAR images

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This paper deals with an original solution for ship wake detection and characterization in SAR images in support of automatic procedure for ship traffic monitoring.

Maritime surveillance is of interest for several projects [1]-[5] and international panels [6] with various aims, such as humanitarian aids, national security, environmental protection and risk management, and also it is under consideration by ESA in the framework of the European crisis response architecture [7].

Vessel traffic monitoring requires collecting several information on the area of interest: detection and, if possible, classification of ships, estimation of their route, i.e. heading and speed.

Since surveillance of seas typically needs frequent observations of wide areas, spaceborne observatories offer better operational performance with respect to airborne, ground and/or maritime systems. Greidanus [8] gives an important summary of spaceborne imaging potential and identifies orbiting Synthetic Aperture Radar (SAR) as key technology.

Classic approaches for ship detection [9] exploit various aspects of ship appearance in SAR images, but the analysis of their wakes, when imaged, is needed for a reliable and

quantitative estimation of the route. In addition, the published algorithms should be reconsidered with respect to the peculiarities of the modern SAR sensors products, first of all their higher resolution.

Ship wakes are identified in SAR image mainly by utilizing the Radon transform. Indeed, a bright (dark) linear feature in the intensity image, as ship wakes appear, is a peak (trough) in the Radon domain, and it is typically detected on the basis of a threshold value. However, the thresholding approach implies the setting of user-defined parameters and a different procedure is needed in order to integrate wake detection in an automatic process.

In this ambit, the paper focuses on a wake detection algorithm conceived to be primarily carried out after ship detection as a validation but also to generate data useful to estimate ship route. An original criterion, suitable for an automatic procedure, will be formulated on the basis wake appearance in SAR images and it will be validated on the available SAR data (COSMO/SkyMed, Tandem-X and ALOS). The key point is that wakes appear as one or more peaks close to a trough in the Radon domain. The dimensions and the position of the search windows are fixed accordingly to the well-known theoretical characteristics of the wakes [10] and the expected ship motion parameters, such as maximum velocity. The final detection validation will be performed through original figures of merit for each detected linear feature, adequate for automatic process

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9243-31, Session 6

A comparative study of RADAR Ka-Band backscatter

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Ka-band RADAR frequency range has not yet been used for Synthetic Aperture Radar (SAR) from space so far, but Space Agencies are aware that this technology may lead to important applications for the next generation of SAR space sensors (e.g.: DEM, cartography, disaster management, object recognition, GMTI, subsidence, ocean currents, vegetation height). In the last five years the European Space Agency (ESA) started activities on the feasibility of a Ka-band SAR instrument and interferometry [1][2]. The studies concluded that a better knowledge is required on backscatter at Ka-band in order to assess the realistic performance of a space SAR for the envisaged applications.

The research presented in this paper, supported by the ESA project "Ka-band SAR backscatter analysis in support of future applications", is aimed at the study of wave interaction at Ka-band for a widely varying range of targets, both natural and manmade. The objective of the study is to define a set of well calibrated and reliable KA-band backscatter coefficients. In our intention, the output of the study shall contribute to answer to the need of a trustworthy Ka-Band backscatter reference and it will be of great value for future technologic applications as support to instrument analysis, design and requirement definition such as Signal to Noise Ratio (SNR), Noise Equivalent Sigma Zero (NESZ).

The paper proposes the results of the critical survey on available datasets at Ka-band together with the available in situ knowledge and ground truth. The selected data is pre-processed in order to harmonize the classification of targets from heterogeneous studies. We define classes of targets keeping in mind that: 1) too general classes will lead to no appreciable differences among the backscatter curves; 2) too specific categories might prevent comparison and practical applications. This step is critical but needed to pave the way for a comparative critical analysis of the datasets. In the paper, we propose several examples giving the priority to the most interesting cases, addressing both the accordance and the differences. When necessary, we discuss the origin of the discrepancies proposing theoretical and empirical motivations of the phenomenon. For this scope, the in situ knowledge and the ground truth data play a key role. Furthermore, we present also a preliminary comparison with ElectroMagnetic (EM) theoretical models aimed at: 1) validating experimental results, 2) justifying possible inconsistencies among experimental data, and 3) extending the range of validity of backscatter curves (e.g.: extrapolating backscatter for not available incidence angles).

The last part of the paper is devoted to lay the foundations for the technological future applications of the study. In particular, we propose a prototypal library software which allows the comparison of theoretical and experimental backscatter coefficients and even gives the chance to interpolate and/or extrapolate values using the best polynomial fitting.

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9244-1, Session 1

Full scale assessment of pansharpening methods and data products

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Quality assessment of pan-sharpened MS images is a much debated topic. Whenever quality is assessed at the full scale of the fusion product, that is of Pan, a consistency measurement of the fusion product with the original, i.e. un-fused, MS dataset, constitutes the spectral quality; a consistency measurement with the original Pan constitutes the spatial quality. The most crucial problem is that if quality is evaluated at the highest resolution of the Pan image, the measured spectral and spatial qualities may follow opposite trends, with the paradox that the least spectrally distorted fused image is that obtained when no spatial enhancement is introduced. The so called spectral-spatial distortion trade off occurs because of incorrect definitions and measurements of either spectral or spatial distortion. In absence of shortcomings, like performing fusion on spatially degraded MS and Pan data in order to evaluate the quality of fusion, the reference for spectral quality is the original MS data to be fused, while the reference of spatial quality is the Pan image. Several methods perform direct comparisons between MS data before and after fusion and this originates the trade off. To overcome this inconvenience, some authors have introduced new definitions of distortion measurements, such that they do not depend on the unavailable true high-resolution MS data, but would measure zero distortions if such data were hypothetically available. The QNR and Khan's protocols foresee separate calculations of spectral and spatial consistencies at full scale and their possible combination to yield a unique cumulative score index.

Alternatively, multi-scale measurements of with-reference indexes, like SAM, ERGAS and Q4, may be extrapolated to yield a quality measurement at the full scale of the fusion product, where a reference does not exist. Experiments on simulated Pléiades data, of which reference originals at full scale are available, highlight that quadratic polynomials having three-point support, i.e. fitting three measurements at as many progressively doubled scales, are adequate (over-fitting is not rewarding). Furthermore, Q4 is more suitable for extrapolation than ERGAS and SAM. The Q4 value predicted from multi-scale measurements and the Q4 value measured at full scale thanks to the reference original, differ by very few percents for six different state-of-the-art methods that have been compared. The cumulative scores of QNR and Khan's protocols have also been calculated at full scale. Notwithstanding all indexes are normalized in [0,1], native full scale (QNR and Khan's) and extrapolated (Q4) measurements cannot be compared in values with one another, but the compared methods can be ranked in terms of:

a) Q4 calculated at full scale from the 0.8 m originals,

b) Q4 extrapolated from its measurements at 3.2 m, 6.4 m and 12.8 m,

c) QNR calculated at full scale,

d) Khan's cumulative quality index calculated at full scale.

Given that a) is the reference gold, the ranking of methods provided by b) c) and d) are compared to that of a) and the most fitting protocol at full scale, among b), c) and d), is derived.

The multi-scale extrapolated Q4 is a valid alternative to QNR and Khan's indexes, especially because:

i) QNR may be sensitive to misalignment of MS and Pan data sets, that cause improper increments in its value.

ii) Khan's spectral and spatial distortion indexes require all system MTFs (both MS and Pan) that may be crucial.

As a last remark, deficiencies and inadequacies of individual quality assessment protocols and related indexes, as well a certain lack of clarity on the topic, together with the fact that pan-sharpening is substantially an ill-posed problem, are mostly responsible for the abnormal spread of low-grade pan-sharpening methods in the scientific literature.

9244-2, Session 1

Methods and metrics for the assessment of Pan-sharpening algorithms

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Recent remote sensing applications require sensors that provide both high spatial and spectral resolution, but this is often not possible for economic and constructive reasons. The "fusion" of images at different spatial and spectral resolution is a method widely used to solve this problem. The particular data fusion technique called pan-sharpening is the synthesis of hyperspectral or multispectral images to the higher spatial resolution of a panchromatic image. The synthesis of fused images should be as close as possible to those that would have been observed if the corresponding sensors had the spatial resolution of the panchromatic sensor.

Pan-sharpening techniques have been applied in this work to simulate PRISMA images. The work presented here is indeed part of the Italian Space Agency project "ASI-AGI", which includes the study of a new platform, called PRISMA, consisting of an hyperspectral sensor (HS) with a spatial resolution of 30 m and a panchromatic sensor (PAN) with a spatial resolution of 5 m, for monitoring and understanding the Earth's surface.

Firstly, PRISMA images have been simulated using images from MIVIS, AVIRIS and Quickbird sensors. MIVIS and AVIRIS are two hyperspectral sensors with spatial and spectral characteristics similar to PRISMA. Quickbird is a multispectral sensor that has been used to test the effectiveness of fusion algorithms not only for hyperspectral datasets but also for multispectral data.

Then several existing fusion methods have been tested in order to identify the most suitable for the platform PRISMA in terms of spatial and spectral information preservation. Both standard and wavelet algorithms have been used: among the former there are Principal Component Analysis (PCA) and Gram-Schmidt transform (GS), and among the latter are DWT (Discrete Wavelet Transform) and the "à trous" wavelet transform (ATWT). Also the Color Normalized Spectral Sharpening (CN) method has been used.

In this work, in particular, we focused on the assessment of the effectiveness of image fusion methods. Numerous quality metrics have been used to evaluate spatial and spectral distortions introduced by pan-sharpening algorithms. We used statistical parameters as the relative shift in the mean, the relative shift of standard deviation, correlation coefficient, entropy and increase in information, but also "universal indexes" such as RMSE (Root Mean Square Error) and ERGAS ("Erreur Relative Globale Adimensionnalle de Synthèse"). In addition we used also third order statistics and classification based metrics performed by the software SIAMTM.

Finally various strategies were adopted to provide a final rank of alternative algorithms/products assessed by means of a battery of quality indexes. All implemented statistics have been standardized, three different methodologies have been used to achieve a final score and a classification of pan-sharpening algorithms.

Currently a new protocol is under development to evaluate the preservation of spatial and spectral information in fusion

methods. This new protocol should overcome the limitations of existing alternative approaches and be robust to changes in the input dataset and user-defined parameters.

9244-3, Session 1

A method for generating high resolution satellite image time series

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There is an increasing demand for satellite remote sensing data with both high spatial and temporal resolution in many applications, e.g. precision farming is a very typical one among them. Monitoring of detailed stationary information on crop at a moment is very important to determine the crop status and also useful to manage farming activities. On the other hand, it is also crucial to capture consecutive temporal change information on crop during a period, for example crop growth monitoring, pet and disease control etc. However so far it is still a big challenge to simultaneously improve spatial resolution and temporal frequency due to the technical limits of current remote sensing satellite system. To this end, conventional research and development have been focusing on two aspects respectively. One aspect is to enhance the spatial resolution using methods of super resolution, pan-sharpen etc. which can produce good visual effects, but cannot preserve spectral signatures and result in less analytical value. Another aspect is to shorten temporal frequency by time interpolation, which actually doesn't increase informative contents at all.

In this paper we first presented a novel method to simulate high resolution time series data by combing low resolution time series data and a very few high resolution data only. Our method starts with a pair of high and low resolution data set, and then a spatial registration is done by introducing LDA model to map high and low resolution pixels correspondingly. Afterwards, temporal change information is captured through a comparison of low resolution time series data, and the temporal change is then projected onto high resolution data plane and assigned to each high resolution pixel according the predefined temporal change patterns of each type of ground objects to generate a simulated high resolution data. A preliminary experiment shows that our method can simulate a high resolution data with a reasonable accuracy.

The contribution of our method is to enable timely monitoring of temporal changes through analysis of time sequence of low resolution images only, and usage of costly high resolution data can be reduces as much as possible, and it presents a great cost performance way to build up an economically operational monitoring solution for agriculture, forest, land use investigation, environment and etc. applications.

9244-5, Session 1

Spatial resolution enhancement of hyperspectral image based on the combination of spectral mixing model and observation model

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Attributed to the advances in remote sensing technology, the image data acquired by remote sensors have steadily grown from one-band panchromatic (Pan) image to multispectral (MS) image with a few bands to hyperspectral (HS) image with hundreds of bands. Compared to the others, HS image is capable of providing more abundant and detailed spectral information which is helpful for interpretation, classification and recognition. With the solid development of aeronautic and astronautic technology, HS imaging has been widely used in tremendous military and civilian applications. However, a tradeoff between spatial and spectral resolutions usually exists in HS images, due to optical and physical limitations, data transfer and storage requirement, and some other practical reasons. As a result, the spatial resolution of HS image is normally lower than that of MS/Pan image. While in practice, many applications require both spatial and spectral precision, which inspired the research on spatial resolution enhancement techniques for HS images.

In this paper, a novel HS image spatial resolution enhancement algorithm is presented, dealing with the case with two available observations of the same scene (a low-spatial high-spectral resolution HS observation and a high-spatial low-spectral resolution MS observation). The newly proposed method is based on the combination of spectral mixing model and observation model for the two observations, and the enhanced HS image is estimated according to the spectrally enhanced endmember signature matrix and the spatially enhanced fractional abundance matrix, and of course, with appropriate treatment with noises in both types of models. Specifically, linear mixing model (LMM) and linear observation model (LOM) are employed, and the HS and MS observations are unsupervised unmixed by using coupled nonnegative matrix factorization (CNMF) technique. Simulative experiments are employed for verification and comparison with some state-of-the-art spatial resolution enhancement methods for HS images using unmixing technique. The experimental results demonstrate the outperformance of the proposed method over the compared ones in both spectral distortion reduction and noise resistance.

9244-6, Session 2

Efficient hyperspectral image segmentation using geometric active contour formulation

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A region based active contour segmentation for object detection and identification in hyperspectral imagery captured in a complex background environment is one of the most challenging tasks in image processing and computer vision areas, especially for objects that have non-homogeneous textures. Automatic object segmentation has been playing an important role in several computer vision applications such as object interpretation, identification and classification. Active Contour Models (ACM) has been utilized extensively for unsupervised adaptive segmentation and automatic object region and boundary extraction. In this paper, we present a new formulation of geometric active contours that embeds the local hyperspectral image information for an accurate object region and boundary extraction. In conventional geometric active contour models, the evolving curves are evaluated as the zero level sets of a signed distance function in two dimensions. Our method utilizes prior knowledge of the intensity of the object of interest to guide the curve evolution of the level set functional. We exploit Self Organizing Map (SOM) unsupervised neural network to train our model. The segmentation process is achieved by the construction of a level set cost functional, in which, the dynamic variable is the Best Matching Unit (BMU) coming from SOM map. In addition, we use Gaussian filtering to discipline the deviation of the level set functional from a signed distance function and this actually helps to get rid of the re-initialization step that is computationally expensive. The proposed technique drives the motion of the zero level set functional towards the desired objects regions and boundaries by embedding local hyperspectral image information. By using the properties of the collective computational ability and energy convergence capability of the ACM energy functional, our method optimizes the geometric ACM energy functional with lower computational time and smoother level set functional. The proposed algorithm starts from feature extraction from raw hyperspectral images. In this step, the Principal Component Analysis (PCA) transformation is employed, and this actually helps in reducing dimensionality and selecting best sets of the significant spectral bands. Next, we apply our modified geometric level set functional based ACM on the optimal number of spectral bands determined by the PCA. In general, this process starts with initial ACM contours that are applied on each band of the PCA image, and ends up with final optimal contours which represent

actual boundary points of the objects of interest. The optimal boundary is selected from the resultant PCA bands by applying statistical analysis. By introducing local significant spectral band information, our proposed method is capable to force the level set functional to be close to a signed distance function, and therefore considerably remove the need of the expensive re-initialization procedure. In addition, our region based level set method is able to segment hyperspectral images with intensity inhomogeneity and also converges after a small number of iterations, providing the ability for real-time applications. To verify the effectiveness of the proposed technique, we use the Resonon Pika II hyperspectral camera, which provides 240 spectral channels that ranges from 400-900nm with 2.1nm spectral resolution, to capture real-life images and test our algorithm in varying textural regions. More specifically, the proposed algorithm is tested on the segmentation of various objects in a number of different hyperspectral images. This framework can be easily adapted to different applications for object segmentation in aerial hyperspectral imagery.

9244-7, Session 2

A fuzzy segmentation tool for remote sensing data

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Remote sensors collect data by detecting the energy that is reflected from Earth, and passive sensors record radiation that is reflected from Earth's surface, usually from the sun. These sensors can be on satellites or mounted on aircraft. Remote sensing data are an important source of information for a variety of applications, such as coastal mapping applications and erosion prevention, hazard assessment, monitor land use, map wetlands, and chart wildlife habitats, for example. One of the most important task for these data analysis is the segmentation. Segmentation means the action of merging neighbouring pixels into segments (or regions), based on their homogeneity or heterogeneity parameters. Methods of image segmentation become more and more important in the field of remote sensing image analysis in particular due to the increasing spatial resolution of imagery. In fact, those methods become popular with the availability of very high resolution imagery and their characteristics: the high level of detail, spectral variance, among others. Traditional image segmentation methods, also called hard segmentation methods, looks for delineating discrete image objects with sharp edges, which cannot be always possible, mainly considering that many geographic objects, both natural and manmade, may not appear clearly bounded in remotely sensed images. A fuzzy approach seems natural in order to capture the structure of objects in the image and takes into account the fuzziness of the real world and the ambiguity of remote sensing imagery is potentially more appropriate than a hard segmentation to resolve the spectral and spatial confusions. The main goal of this work is define boundaries of objects in an image, such as deforestation areas. This proposal aims to be faster than other segmentation approaches inside the TerraLib tools by considering only the neighbourhood of a selected pixel. TerraLib is an open source Brazilian Geographic Information System (GIS) classes and functions library, allowing a collaborative environment and its use for the development of multiple GIS tools, e.g. TerraAmazon and TerraView. This work proposes the use of image's tone and colour to select and define objects in remote scenes based on fuzzy rules. The algorithm is able to identify an object from an initial pixel value in a specific space location. The fuzzy set is defined by an input tolerance level, which can be adjustable according to the desired granularity of the selection. Based on the subrange, the algorithm will select any pixels that are the same value as the selected one, plus any pixels that are inside the tolerance range, meaning shades darker or brighter. It is important to observe that the proposal methodology is not limited by the selection of only one object, that is, the mask can be designed by a set of objects with different features and tolerances. Since the object is delimited, the algorithm returns its size and proportion inside the scene. The quality of the individual segmentation results is evaluated based on multi-spectral Landsat 5-TM data. This is done by visual comparison, which is supplemented by a detailed investigation using visual interpreted reference areas.

9244-8, Session 2

Automatic large-volume object region segmentation in Lidar point clouds

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LiDAR is a remote sensing method which produces precise point clouds consisting of millions of geo-spatially located 3D data points. Because of the nature of LiDAR point clouds it can often be difficult for analysts to accurately and efficiently recognize and categorize objects. The overall goal of this paper is automatic large-volume object region segmentation in LiDAR point clouds.

The point cloud data is initially pre-processed into local histogram bins. These are obtained by splitting the point cloud into a grid in the x and y direction. The individual bases of this grid are extended up vertically in the z direction to encompass all the points within the base. The data is then binned again which results in a series of voxels which contain the x, y and z location information as well as the density of points within that voxel. From these voxels, a histogram can be created that defines the density and distribution of the point cloud at each base location. In addition to providing a feature set that includes local grounds at each location, this pre-processing step also increases efficiency by consolidating the point cloud without losing location data.

From these local histogram bins the point cloud is represented as a series of vertical columns where the column height will be the value of the highest point within that base location. This is equivalent to representing the point cloud from a nadir view. Once the point cloud is segmented into columns, a seeded region growing algorithm is applied. The seeds are selected based on two conditions. The first is similarity to neighbors. A normalized standard deviation between the column and its nearest neighbors is computed. The second condition for seed selection is the relative maximum Euclidean distance between the nearest neighbors. Columns are identified as seeds if the similarity between the column and its neighbors is higher than a threshold and the maximum Euclidean distance between a column and its neighbors is below a threshold. The threshold for similarity is determined using Otsu's method. The threshold for distance is determined by using the smallest 10% of calculated distances. Once seeds are detected, the neighboring seeds are merged to form seed regions then labeled accordingly.

From these seed regions of 3-D columns, neighboring columns are examined and sorted based on Euclidean distance to neighboring regions, starting with the smallest distance. Any column whose neighbors have more than one label is assigned to a region with the smallest Euclidean distance between the column and the region mean. Because of a tendency for over-segmentation the segmented regions are post-processed and integrated if they are significantly small. The region is integrated into the region with the smallest difference from its own mean.

Overall this method is extremely accurate in large-volume region segmentation. In addition to obtaining accurate segmentation results, the initial separation of the point cloud data into local histograms results in an efficient algorithm, accurately segmenting large volume objects in a region of over 9,000 points in ~10 seconds. Additionally the local histograms contain important feature and geometric information which can be used for object classification.

9244-9, Session 2

Edge-crease detection and surface reconstruction from point clouds using a second-order variational model

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Nowadays, the increasing availability of remote sensing active systems makes it possible to produce detailed representations of objects on the ground in the form of dense 3D point clouds. On the one hand, LiDAR data acquisitions are now available with point densities ranging from 1 to 50 pts/m2, on the other hand, 3D point clouds with densities comparable to LiDAR can be achieved by applying Tomographic SAR Inversion (TomoSAR) to multiple very high resolution (VHR) SAR images acquired at different viewing angles [1]. In terms of data availability this is of great relevance, in particular thanks to the large amount of images provided by new spaceborne VHR SAR sensors like those mounted on Cosmo-SkyMed and TerraSAR-X satellites. This scenario offers the possibility to achieve significant improvements in all those human activities where information extracted from the real 3D geometry of objects is of major importance (urban monitoring activities, identification of man-made structures, building reconstruction).

Moreover, the increasing level of detail available in the produced data must be rigorously followed by an increasing accuracy, effectiveness, automation, of the methods of analysis.

Working directly on the original point cloud is a non-trivial task. Most of the techniques available in the literature cope with the problem of segmenting the scene and recognizing objects by means of model-based or context-driven approaches [2][3]. These methods are shown to be effective mostly on specific contexts, and basically they rely on prior knowledge. Other techniques (most of them coming from the literature of image processing) are based on segmentation steps where more general geometric features are detected (e.g. boundaries, edges, creases, slopes) without assuming any predefined model [4][5]. A limitation of these methods is that most of them require the unstructured point cloud to be rasterized or interpolated into a regular grid. When the density of the point cloud is low this may results in a potential loss of detail.

However, the generalization of these methods on unstructured grid of points is not straightforward.

In this paper we address the problem of edge-crease detection and surface reconstruction from 3D point clouds. This work is intended to be a first step for the generalization of a recently proposed variational model of second order based on the Blake-Zisserman functional, which has been successfully applied to the automatic segmentation of digital surface models (DSMs) [6]. The Blake-Zisserman model represents a generalization of the well-known Mumford-Shah, and provides a general framework for both data segmentation and surface reconstruction. The model is made up of several terms, which interact each other for obtaining a smooth approximation of the data (more precisely a piecewise linear approximation) that preserves the morphology of constant gradient areas. These reconstructed regions are explicitly detected by partitioning the data using the graph of two special functions: the edge-detector function, which detects discontinuities of the data, and the edge/crease-detector function, which also detect discontinuities of the gradient. This model overcomes several drawbacks of the widely used first order models, such as, oversegmentation of steep gradients, lack of second order information, degraded resolution on multiple junctions of boundaries. We aim at extending this approach also to the case of unstructured clouds of points and finding proper ways for generalizing the method by trying to keep advantage from the intrinsic nonhomogeneous characteristics of the data. To address this challenging problem, in this paper we investigate the definition of a general algorithm based on Finite Element Methods (FEM). In this framework, a fundamental step is the planning of proper strategies for the representation of the unstructured domain.

Accordingly, we address the problem of defining an effective strategy for exploiting the non-homogeneity of the points (in terms of both density and distribution) in two steps: 1) we localize potential boundary points by means of triangulation of the domain, and 2) we activate automatic procedures of self-adapting refinement of the triangulation. Due to the intrinsic properties of the variational model adopted, during the segmentation process the variations of the approximating functions are steadily kept bounded. In practice this allows for a decomposition of the domain with consequent refinement of the representation of the original data. In particular, our strategy is aimed at driving this procedure in order to focus the recovering of information on boundaries. The full paper will present the analytical details of this methodology and preliminary results obtained on LiDAR data.

9244-10, Session 2

Three-dimensional building roof boundary extraction using high-resolution aerial image and Lidar data

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This paper presents an automated method for rectilinear building roof boundary extraction, based on the integration of high-resolution aerial image and LiDAR (Light Detection and Ranging) data. The proposed method is formulated as an optimization problem, in which an objective function is developed to represent the building roof boundaries in an object-space coordinate system. Three-dimensional polylines representing building roof boundaries are obtained by optimizing the objective function using the dynamic programming optimization technique. The objective function is firstly developed in the line (L) and column (C) image coordinate system. It is derived from the original snakes-based energy function by considering that building roof boundaries can be modeled by combining step edge and corner profiles. As most of building roof boundaries is rectilinear structures, right angle corners are mathematically enforced into the image-space objective function. Second, the resulting image-space objective function is modified in order to model building roof boundaries in object space, as follows: 1) the collinearity equations, along with the interior and exterior orientation of the camera, are the basic requirements for establishing a mathematical relation between a point (P(X, Y, Z)) in an X, Y, Z - object-space reference system and the corresponding point (p(L, C)) in the L, C – image coordinate reference system. The resulting mathematical relation allows us to express the image-space objective function into the X, Y, Z – object-space coordinate system; 2) as this objective function is ambiguous, we model the surface (terrain and buildings) using a LiDAR-derived TIN (Triangulated Irregular Network), which allows the enforcement of each polyline vertex (P(X, Y, Z)) to belong to a planar face of the TIN. This also allows the elimination of the Z-coordinate from the resulting object-space objective function; 3) as any building roof boundary is characterized by large discontinuities, we enforce a slope restriction to penalize polyline vertices that are far from the near TIN discontinuity. As the resulting object-space objective function interrelates simultaneously only six coordinates of three sequential vertices, we used the time-delay dynamic programming algorithm to optimize it. The optimization scheme is applied separately to each building roof, allowing an initial polyline to slide on the roof surface and its prolongation, stopping when an optimal position and shape are found. The initial polyline of each building roof is derived by segmenting the TIN to isolate each building roof, from which the initial polyline is extracted by following its boundary. In order to experimentally evaluate the proposed approach we used one high-resolution aerial image with GSD of 25 cm and a LiDAR point cloud at an average density of 2 points per m2. The results of our experiment showed that the proposed method satisfactorily performed the task of extracting different building roof boundaries from aerial image and LiDAR data. The experimental results also showed that the main advantage of the method is that it can satisfactorily model the local context, as e. g., shadows or another building roof boundary that are nearby and approximately parallel to the selected building roof boundary.

9244-11, Session 3

Sentinel 2: geometric calibration during commissioning phase

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Sentinel-2 is a multispectral, high-resolution, optical imaging mission, developed by the European Space Agency (ESA) in the frame of the Copernicus program of the European Commission. In cooperation with ESA, The Centre National d'Etudes Spatiales (CNES) is responsible for the image quality of the project, and will ensure the CAL/VAL commissioning phase.

Sentinel-2 mission is devoted the operational monitoring of land and coastal areas, and will provide a continuity of SPOT- and Landsat-type data. Sentinel-2 will also deliver information for emergency services. Launched in 2015 and 2016, there will be a constellation of 2 satellites on a polar sun-synchronous orbit, imaging systematically terrestrial surfaces with a revisit time of 5 days, in 13 spectral bands in visible and shortwave infra-red. Therefore, multi-temporal series of images, taken under the same viewing conditions, will be available.

This paper presents first briefly Sentinel-2 system, and the main geometric image quality requirements: geolocation with and without ground control points, multi-temporal and multi-spectral registration. Then, it will give an overview of geometric processing at level 1 to produce ortho-images. Then, the paper will presents the methods foreseen during commissioning phase so as to calibrate the alignment biases, the focal plane lines of sight, and assess the geometric performances of the system.

9244-12, Session 3

Automatic registration of multispectral images through maximization of mutual information

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More and more applications in Earth and Space Science require integration of data acquired from multiple sources. This integration provides information for intelligent navigation and decision support systems in increasingly real-time applications. In Earth Science, data is represented by multiple temporal and spectral acquisitions (taken from ground, satellite and airplane), then, for an efficient data integration, an automatic, reliable and accurate image registration is essential.

In this paper we propose a method to get fine registration of high resolution multispectral images. The algorithm assumes that a coarse registration, based on ancillary and geometric information, has been already performed. It is known that various distortions still remain, even after registration based on orbit data, due to the combined effects of Earth rotation and curvature, view geometry, sensor operation, variations in platform velocity, atmospheric and terrain effects.

The algorithm grounds its main idea on the information-theoretic approach, presented by Viola in 1995, to register volumetric medical images of different modalities. Registration is achieved by adjustment of the relative position and orientation until the mutual information between the images is maximized. The idea is that the joint information is maximized when the two images are correctly registered. The mutual information allows to join the information of two images from a stochastic point of view, providing us with the relationship between the two images, without any prior model. This approach works directly with image data (so no pre-processing or image segmentation is required) but in principle it can be applied in any transformed domain. Moreover, while the original work was thought to make registration by looking in a limited search space (translation and orientation), we extend the class of transformation that establish the correspondence between the two images allowing more complex transformations as scaling, shearing (a trapezoidal distortion of the image) or applying a polynomial model, similarly to the Rational Function Model, largely used in the mapping community.

The maximization of the target function is usually performed using the stochastic gradient descent algorithm. However a known drawback of such optimization method is the deadlock in local maxima that can occur due to the space similarity of topographic features, intrinsic in remote sensed images. Another difficulty consists in the correct choice of the learning rate, the speed with which the algorithm converges. To overcome these problems, we performed the optimization through the simulated annealing, a probabilistic method based on the discrete-time inhomogeneous Markov chain to look for a global minima of a cost function.

We applied the algorithm on a SPOT5 couple of 60x60km images, achieving registration of chips of 256x256 pixels size at time. Accuracy has been deduced by comparing the results with the Normalized Cross-Correlation method implemented as the core algorithm of a commercial software. On 143 chips taken throughout the image we get an average difference with NCC of 0.25pixels and a standard deviation of 1.7pixels for translation and an average difference of 0.015deg and a standard deviation of 0.32 for rotation.

9244-13, Session 3

On resampling algorithms for the Meteosat Third Generation rectification: feasibility study for an operational implementation

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The Meteosat Third Generation (MTG) Programme is the next generation of European geostationary meteorological systems. The first MTG satellite, which is scheduled for launch at the end of 2018/early 2019, will host two imaging instruments: the Flexible Combined Imager (FCI) and the Lightning Imager. The FCI will continue the operation of the SEVIRI imager on the current Meteosat Second Generation satellites (MSG), but with an improved spatial, temporal and spectral resolution, not dissimilar to GOES-R (of NASA/NOAA).

The transition from spinner to 3-axis stabilised platform, a 2-axis tapered scan pattern with overlaps between adjacent scan swaths, and the more stringent geometric, radiometric and timeliness requirements, make the rectification process for MTG FCI more challenging than for MSG SEVIRI. The effect of non-uniform sampling in the image rectification process was analysed in an earlier paper. The use of classical interpolation methods, such as truncated Shannon interpolation or cubic convolution interpolation, was shown to cause significant errors when applied to non-uniform samples. Moreover, cubic splines and Lagrange interpolation were selected as candidate resampling algorithms for the FCI rectification that can cope with irregularities in the sampling acquisition process.

This paper extends the study for the two-dimensional case focusing on practical 2D interpolation methods and its feasibility for an operational implementation. Candidate kernels are described and assessed with respect to MTG requirements. The operational constraints of the Level 1 processor have been considered to develop an early image rectification prototype, including the impact of the potential curvature of the FCI scan swaths. The implementation follows a swath-based approach, uses parallel processing to speed up computation time and allows the selection of a number of resampling functions. Due to the tight time constraints of the FCI level 1 processing chain, focus is both on accuracy and performance. The presentation will show the results of our prototype with simulated FCI L1b data.

9244-14, Session 3

Automatic outlier suppression for rigid coherent point drift algorithm

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1. PURPOSE

The main goal of point pattern registration is to obtain correspondence between two different point sets and determine the transformation that maps one set to the other. Point sets are usually extracted from data of different types, such as image edge points, which are often corrupted by outliers. How to deal with outliers is of vital importance in point set registration. According to the literature [Myronenko, 2010], these transformations of finite degrees of freedom are rigid, which are the major cases in real life. Rigid transformations include Euclidean, similarity, affine and projective transformations. In this paper, we will focus on these transformation forms.

Point pattern registration including the hard assignment and soft assignment approaches has attracted much attention. The appearance of combination of Gaussian mixture models (GMM) and expectation maximization (EM) marked the beginning of true probability based method. Its typical representative is Coherent Point Drift (CPD) algorithm, which treats one point set as GMM centroids (named model point set), and then fits it to the other (named target point set). It uses the EM framework, where the point correspondences and transformation parameters are updated alternately. Though CPD adds a uniform term to model outliers, the outliers have always been involved in operation until the CPD converges regardless of how they are modeled. So the anti-outlier performance of CPD is not robust enough. This paper proposed an automatic outlier suppression mechanism (called AOS-CPD) to overcome the shortages of CPD.

2. METHODS

A. The shortages of the CPD algorithm

The matching probability matrix P (M?N) between model point set (M points) and target point set (N points) in CPD is defined as the posterior probability of model points for a given target point. The row and column direction of P represent the M model points and the N target points respectively. For each model point (or each row of P), the target point corresponding to the maximum probability in this row is considered as the matching point. The problem is: there may be more than one model point corresponding to the same target point and some target points may not be selected at all. This means that there are outliers in point sets. In order to simulate the effect of outliers, CPD adds a uniform term to mixture model, but it does not carry out further processing.

In addition, CPD uses a parameter w to represent the weight of outliers [Myronenko, 2010]. In order to get better performance, several values of w need to be tested to find the optimum one, even though the outlier ratio has been acquired. This implies that w does not reflect the outlier ratio and thus cannot be relied on.

B. Automatic outlier suppression

Inspired by the concept of bidirectional normalizations of matrix and outlier rejection in probabilistic relaxation labeling (PRL) algorithm, we propose an AOS mechanism that follows the steps: first, inliers are judged; then, transformation relationship is fitted using accurate matching point sets; finally, the model point set is forced to move coherently to target point set by the fitted relationship.

For matrix P, each model point (or each row of P) has N probability values, which represent matching probability between this model point and N target points. The candidate matching target point of this model point should have maximum value in these probabilities. Furthermore, if this probability value is also the maximal in its column, we can determine that this candidate point is the true matching point. If it is not, just go to next row. The accurate matching point sets will be obtained after analyzing all rows of P.

If the cardinality of accurate matching point set is greater than a certain threshold, transformation parameters ? between the two point sets can be fitted using the least square method. The parameters calculated by this way will be more accurate and more effective for transformation of model point set. Finally, the transformed model point set is imported into EM algorithm again and the cycle repeats itself. The iteration finishes when P converges or the cardinality of accurate matching point set reaches a maximum. Benefitted from this mechanism, AOS-CPD can significantly improve the anti-outlier performance, and greatly reduce execution time of the algorithm as well. We also expect to explore more information about P in the future work.

The covariance of GMM is used to characterize coordinate position error of two point sets. In order to adapt to the transformed point sets, CPD updates the covariance in EM iteration. The coherent drift of model point set will speed up when the AOS mechanism is embedded, so we must update the covariance using the newest position error before reentering the EM iteration.

3. RESULTS AND CONCLUSIONS

To evaluate our approach, we present experimental results on both synthetic data and real data. The first group of experiments tests the anti-outlier ability between non-accurate model point set and accurate target point set. The second group of experiments is between accurate model point set and non-accurate target point set. The third group of experiments is carried out on edge points of real image. The execution time is also compared in each experiment. In conclusion, compared with CPD algorithm, the anti-outlier performance of AOS-CPD is increased by about 15% and the execution time is reduced by more than 50%. It offers a good practicability and accuracy in rigid point pattern registration.

9244-16, Session 4

Atmospheric normalization via multi-image pseudo-invariant features

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This paper presents a linear multi-image approach for the automatic relative normalization of a satellite time series. The use of multi-image pseudo-invariant features (MI-PIFs) shared in different image combinations allow the extension of the pairwise normalization approach towards a simultaneous and combined Least squares adjustment of all the available images. The basic assumptions of the method are a linear relationship between the DNs of the images and the use of points (MI-PIFs) whose reflectance values are invariant overtime. If both conditions are verified a mathematical model able to handle the correction parameters of all the images can be written through an unified Least Squares problem.

The number of equations of the proposed formulation depends on the number of MI-PIFs extracted, according to the visibility of the same feature in (at least) two images. As the final aim is a multi-image relative normalization where all the images are assumed as sensed data, the removal of rank deficiency (2 parameters in this case) can be obtained by choosing one of the images as reference. This means that its DNs become fixed quantities and equations for both sensed-to-sensed and sensed-to-reference image combinations can be incorporated into the same problem.

An additional check is also performed by exploiting the geometric registration constraint. In other words, the current multi-image implementation must simultaneously satisfy the linear model for relative normalization and the geometric constraint for image registration, providing an additional check of automated matching results. Wrong MI-PIFs are removed with random sampling consensus techniques and their final reordering provides the input for the combined model for relative normalization.

Results on both synthetic and real data are illustrated and discussed to prove the correctness of the implemented approach and its feasibility in real applications.

9244-17, Session 4

Image structure restoration from sputnik with Multi-Matrix Scanners

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Russian remote sensing systems with high spatial resolution such as «Resurs-DK», «Resurs-P», use matrix scanning cameras. There are a lot of CCD matrices in the focal plane mounted to be perpendicular to the direction of flight and which provide a small overlapping of the swaths. Each matrix forms a part of image referred here as a “scan”. In general, the set of the matrices is the base of the optical-electronic device (OED) which allows significantly increasing resolution and the swath. To form multispectral images the set of OEDs are mounted in the focal plane. Due to the suggested design of the sensors there is needed to develop special technologies for image structure restoration aimed to

1) stitching scans to form a continuous image,

2) fuse multispectral images obtained in different moments in order to form a synthetic color image of the earth surface,

3) dropout (hide) color defects in the synthesized color images conditioned by moving and high altitude objects.

The suggested scan structure restoration method provides a sub-pixel geometric stitching and precise radiometric equalization. The result is an image that is equivalent to that which could be obtained by means of a virtual CCD-matrix. The parameters of inside camera’s orientation are calculated, and then applied to geo-referencing and image orthogonal transformation into a map projection. A survey of the one and the same part of terrain is performed by adjacent CCDs with an interval of about 0.05 sec. The orbital SV’s position, orientation angles are changed during this time interval, as well as there is an offset of the underlying surface due to the Earth rotation. Therefore, the geometrical scan registration is described by complex equations, the parameters of which are determined by the parameters of inside and outside camera’s orientation using the coordinates of shared points in the adjacent scans. It is shown that MSE of geometric scan stitching comes to 0.3 pixels.

The geometric scan correction operation runs in parallel. This operation is aimed to eliminate distortions caused by fixed pattern noise of CCD matrix. The radiometric correction algorithms are based on statistical analysis of the input images (Figure 1). The correction function is represented as , where b, b* are input and corrected brightness values, fe, fm are the empirical probability density functions for the pattern and the column numbered m.

Measurement errors of the angular SV’ position and influence of high altitude objects does not allow getting a good model for fusion of multispectral images obtained in different moments. Therefore, the geometrical fusion of multispectral images is performed by use of the analytical model based on equations for geodetic image reference. The residual errors are eliminated by means of a triangulation model that is considered to be the best model describing local image deformations. The paper describes the algorithms for reliable point identification which are followed from the model.

Besides, the original algorithm to eliminate color artifacts caused by moving and high altitude objects is considered. The algorithm does not require any identification and moving object selection and provides with high performance. It is based on usage of the YCbCr color space to receive the RGB components; here the channel G is used for moving objects.

9244-18, Session 4

Hyperspectral imagery restoration based on multisource image fusion

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Recently, hyperspectral imagery is significant as a valuable remote sensing technology can support many applications in commercial and military areas. However, hyperspectral imagery may suffer from missing regions due to various limitations of the acquisition systems. Therefore, the recovery of missing data receives more and more attention.

In theory, data recovery is an ill-posed problem. The information inside the missing regions is totally lost and there is no unique solution. Therefore, different assumptions are proposed to build the relation between the missing part and its known neighborhood. In the literature, the reconstruction approaches fill in the missing part by using information from the surrounding areas. However, once the missing region is large, there may not be sufficient information in the neighborhood. Fortunately, hyperspectral sensors are usually flown with boresighted and higher resolution panchromatic sensors. Such sensor system approaches offer an opportunity to make up the deficiency in a multi-source way due to similar textures. Coincident panchromatic imagery is helpful as it provides some supplementary information about the missing part. In this paper, we propose a novel hyperspectal data recovery method based on coincident panchromatic imagery based on image fusion.

Concretely, the inpainting over missing regions can be defined as a minimization problem. The goal of the minimal optimization is consistent as possible between the gradient of the polluted image and the gradient field of the panchromatic or multi-spectral image.A unique solution of the Poisson equation is obtained with Dirichlet boundary conditions.

In this paper, we present a number of experimental results in order to demonstrate the effectiveness of the proposed method. In the simulation experiments, the data in 0.43-0.6?m wavelength range, 53 bands, come from airborne hyperspectral system ROSIS. The original image (488 by 582 pixels) of band 20 of the data is added a strip with 17-pixel width to simulate image part missing. Moreover, a panchromatic image is simulated with integration of the bands in the visible range. We restore the missing part band by band. From the convenience of visual judgment, the proposed method gives better recovery results, compared to the results of the other methods, such as Total Variation (TV), ENVI.

Due to hyperspectral image, the spectral signature recovery effect must be evaluated. The experimental results show the original and recovered spectral signatures of a pixel situated in the missing strip. In addition, we employ the average of RMSE (ARMSE) to analyze the entire results of the spectral signatures recovery. For TV, ENVI, and the proposed algorithm, ARMSE are 0.0485, 0.0440 and 0.0132 respectively. Our methods yields the lowest recovery error.

9244-19, Session 4

Prediction of optimal operation point existence and parameters in lossy compression of noisy images

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In many applications of remote sensing it is necessary to carry out lossy compression of acquired images taking into account that they are (might be) noisy. One way to carry compression then is to perform coding with parameters that correspond

to optimal operation point (OOP) [1]. By OOP we mean such a value of a parameter of a coder that controls compression (is able to change compression ratio) and provides extremum (e.g., minimum of MSE) of a considered reference metric calculated between compressed and noise-free images. Although noise-free image is absent in practice, there exist methods of providing image compression in the neighborhood of OOP in automatic manner [1. 2]. Meanwhile, OOP does not always exist. Its existence depends upon complexity of a compressed image, noise level (variance), a metric considered, and a coder used. Then, an actual task is to predict does OOP exist for a given image to be compressed.

Recently, an approach to prediction of filtering efficiency has been developed [3]. In our new paper, we will demonstrate that the same approach after certain modifications can be useful for predicting OOP existence. Moreover, it is possible to predict parameters of compression in OOP like improvement of PSNR or improvement of visual quality metric (for example, PSNR-HVS-M) in OOP. To carry out such a prediction, two very simple operations are needed. First, a statistic parameter in non-overlapping 8x8 pixel blocks of a compressed image is to be calculated. As such statistic parameter, we propose to use and study properties of two probabilities: P2? that absolute values of DCT coefficients do not exceed 2? (where ? is standard deviation of additive noise assumed zero mean spatially uncorrelated and with a priori known variance) and P2.7? that absolute values of DCT coefficients exceed 2.7?. Second, having a set of test images, we have obtained dependences of the considered metrics on P2? (and on P2.7?) by fitting curves to scatter-plots obtained for several coders.

Then, after estimating P2? (or P2.7?) for a given image and having a corresponding approximating dependence at disposal (which is obtained once and in advance), it becomes easy to predict existence (or absence) of OOP. For example, OOP exists (with high probability) if the predicted improvement of PSNR is positive (larger than zero). If so, it is worth compressing noisy image in the neighborhood of OOP. If OOP does not exist or is not obvious (this holds if predicted improvement of PSNR is negative or about zero), it is reasonable to compress a given image with a smaller compression ratio, i.e., with introducing less distortions. Such recommendations can be put into basis of a fully automatic procedure [4] of component-wise compression of multichannel (multi- or hyperspectral) remote sensing data.

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9244-20, Session 4

Characteristics Analysis of Infrared Polarization for Several Typical Artificial Objects

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When remote sensing and detection to the earth, it is a difficult point to detect and recognize artificial targets under the disturbance of the complex ground clutter. However, the ability to distinguish artificial targets from natural scenery of the remote sensing and reconnaissance system can be promoted effectively by using the differences of infrared polarization information between artificial targets and natural scenery. On account that the differences of polarization properties is an important basis in designing the target recognition method, this paper focuses attention on the application of remote sensing and reconnaissance and makes research on the polarization properties of several typical materials or targets. Firstly, the basic theories of polarization imaging is introduced; then, on the basis of the measured data acquired by LWIR polarization imaging, the rules of DoP and AoP changing with temperature or polarized angle of several typical artificial objects is analyzed and researched. Work of this paper lays the theoretical foundation for the design of remote sensing and detection system based on the infrared polarization information in the future.

9244-21, Session 5

Feature selection of hyperspectral data by considering the integration of Genetic Algorithms and Particle Swarm Optimization

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Currently, for data acquisition, there is an era of massive automatic data collection. Many measurements are systematically collected without the knowledge of which data are appropriate for the problems being addressed. As an example, the trend of hyperspectral imagery is to record hundreds of spectral channels from the same scene and that is useful for characterizing chemical composition of different phenomena.

In the spectral domain, each spectral channel is characterized as one dimension and each pixel is represented as a point in this domain. By increasing the spectral channels in the spectral domain, although data information content is significantly increased, a challenge remains from the standpoint of expected classification accuracy. That is because with a constant number of samples, a higher dimensional set of statistics must be estimated. In other words, although higher spectral dimensions increase the separability of the classes, the accuracy of the statistical estimation decreases, which consequently leads to a decrease in classification accuracy. In this case, the use of feature reduction techniques is of importance.

In this paper, a novel supervised feature selection technique is proposed which is based on Support Vector Machine (SVM) classifier and the integration of Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). Then, the new feature selection technique is applied on a real data set (Indian Pines) and results are compared with a situation when SVM is carried out directly on the input data.

PSO is a well-established technique and its reputation is for the simple conceptual of that and can be implemented in a few lines of code. Furthermore, PSO also have memory, regarding the best local and global positions which can be useful to model the personal and global behaviors of different particle. However, the concept of that is suffered by a few shortcomings such as 1) the swarm may prematurely converge and 2) PSO is highly parameters dependent and results can be considerably different by adjusting different set of parameters. In the same way, in GA, if a chromosome is not selected, the information contained by that individual will be lost. In general, Hybrid GA-PSO is used to overcome these problems.

In the new method, the first population is randomly built in a binary way where 0 shows the absence of the corresponding band and 1 shows the presence of that. Then, the fitness of each particle is evaluated by considering the overall accuracy of classification by SVM over the validation samples. Then, the top-half best-performing individuals are opted. These individuals are regarded as elites. By applying PSO on the

elites, we may increase the ability of searching for the optimal solution. Half of the population in the next generation is produced by enhanced individuals. The remainder is occupied by individuals from crossover and mutation operations. The algorithm keep iterating until the stop criterion is met. Finally, the selected bands are classified by SVM.

Results confirm that the new feature selection approach (including the new feature selection technique and the final SVM classification) is faster than when SVM is directly applied on the raw data and the obtained improvement is 11 seconds of CPU time. The new method also increases the overall accuracy of the situation when SVM is directly applied on the input hyperspectral data by 7 percent. As a result, the new method not only improves classification accuracies but also reduces the CPU processing time.

9244-22, Session 5

Classification of ocean surface slicks in hybrid-polarimetric SAR data

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During the last years, substantial research have been done on developing methods for detection and monitoring of oil spill at sea in synthetic aperture radar (SAR) images. However, operational services like EMSA's CleanSeaNet does not currently provide the user with estimates of oil spill characteristics, like type or thickness. The knowledge of oil type is critical with respect to the measures to be initiated in clean-up operations.

In this paper, we study classification of surface slicks in hybrid-polarimetric C-band SAR data. Hybrid-polarization realizes many of the benefits of quad-polarization, without the reduced swath width. The objective is to develop methodology for classification of oil slicks into various oil types. We aim to discriminate between the following types of slicks: crude oil, plant oil, emulsion, look-alike and clean sea areas. For the Arctic, discrimination of sea ice is also of interest.

The proposed scheme consists of the following steps: (1) pre-processing,(2) feature extraction (3) automatic extraction of clean sea samples, (4) domain adaptation, (5) classification and (6) confidence estimation.

The extraction of clean sea samples is based on the hypothesis that the SAR image consists of a large portion of clean sea pixels, and that these pixels has higher intensity values than the surface slicks. These pixel intensities form the basis of the domain adaption algorithm, in which they are used to construct a transform-function that transforms the backscatter intensities of the test image such that the clean sea backscatter intensity distribution matches the clean sea intensity distribution of the training images. If training data is collected from several SAR images, the training data is standardized to a pre-defined distribution using the same procedure.

To perform the classification, we consider several classifiers, including support vector machine and K-NN. The classifier is pixel based, in which all pixels are classified into one of the oil type classes. However, to prevent spurious errors in the resulting class-map, apply a Markov random field in order to introduce spatial information from neighboring pixels.

The proposed methodology is demonstrated on a hybrid-polarimetric SAR data simulated from Radarsat-2 quad-pol data. The extracted features and classifiers are successfully applied to SAR data covering oil-in-sea experiments outside Norway and the Deepwater Horizon incident in the Gulf of Mexico. The results show that the classifiers are able to discriminate crude oil, plant oil, look-alikes and clean water, but struggle to separate emulsion from crude-oil.

Due to the potential of hybrid-polarimetric SAR data to support wide swath widths, we conclude that hybrid-polarity is an attractive mode for future SAR based oil spill monitoring and may distinguish some surface slicks from other.

9244-23, Session 5

Applying manifold learning to classification of closely spaced objects using time signatures

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In many remote sensing applications with dense object scenes, closely spaced objects (CSOs) present classification challenges by obscuring the true number and location of point source objects on a sensor focal plane array (FPA). In the absence of a priori knowledge of the number or characteristics of CSO targets, traditional CSO processing techniques can be computationally prohibitive. In this paper, novel, machine-learning approaches are proposed to aid estimation and classification of CSOs comprised of rotating objects, by exploiting the lower dimensional manifold structure in the higher-dimensional time signature data. As rotational motions are inherently nonlinear, nonlinear dimensionality reduction techniques such as Isomap are described for this application. Initial, computationally fast, proof-of-concept demonstrations using point source time signatures from simple, rotating conical objects show promise for feature selection for estimation and classification of CSOs.

9244-25, Session 5

Unsupervised feature selection based on the maximum tangent discrimination of band vectors in prototype space for hyperspectral imagery

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In this paper, an effective unsupervised feature selection (FS) method called MTD has been proposed based on geometrical criteria in the prototype space (PS). The PS is constructed based on the spectra of endmembers or cluster centers as the representatives of the phenomena present in the image, and demonstrates the image bands as scattered points. MTD uses two criteria defined by the tangent of the angles between band vectors in the PS to describe the band correlations. In the proposed method, the optimal feature size is determined as an embedded process. The method was evaluated using the experiments conducted by a real data set (i.e., Indian Pine) and was compared with the LP and G-FS methods, in terms of the overall accuracy (OA) and kappa coefficient (KC) measures achieved by the classifiers QDC, kNN, LDC and SVMs. Generally, two experiments were conducted using the original and noise-whitened status of the data set. The other evaluations that were used in the experiments are standard deviation (SD), Friedman test and computational cost. In the first experiment, the optimal features were selected for the original data set. According to the results obtained by learning curves, the MTD method performed better than the LP and G-FS methods. To evaluate the efficiency of the unsupervised FS methods, the OAs and the optimal feature sizes, which were obtained in an unsupervised fashion by learning curves, were compared together. The optimal feature sizes achieved by MTD were close to the number of classes reported in the data set. The OA of MTD, corresponding to its optimal feature size in an unsupervised fashion, was much better than the OAs of LP and G-FS. In order to evaluate the efficiency of the FS methods, the case of applying the full dimensional data was also considered in the experiments. The data sets were classified only by kNN and SVM classifiers in full dimensionality. The comparison between SVMs in full dimensionality and QDC in reduced space showed that the former had a significantly smaller OA and a larger SD. In addition to the comparisons mentioned previously, the Friedman tests were conducted on the data set, which showed that the difference among the FS

methods were statistically significant. The second experiment was conducted by using the noise-whitened data set. The Friedman test on the data set once again demonstrated similar results as in the original data sets. Once more, the MTD algorithm reached higher accuracies in comparison with other methods. Furthermore, MTD profited from noise whitening as they achieved higher accuracies with less number of features. The noise whitening improved the accuracy of the LP and G-FS methods as the optimal feature size increased. Nevertheless, an improvement in the OAs of all methods and a decrease in their SDs were remarkable in the data set. The FS methods were also evaluated in terms of computational cost. For the SVM classifier in the full dimensionality status, the computational cost was higher than that of conducting FS and classification processes (i.e., FS+classification). In sum, MTD demonstrated better results in an unsupervised fashion in comparison to the situation in which learning curves were used for the LP and G-FS methods. Meanwhile, the OAs of MTD obtained in an unsupervised manner were almost the same as the maximum OAs obtained by the learning curves.

9244-26, Session 6

Urban land-cover classification based on airborne hyperspectral data and field observation

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Urban environment is generally complicated, mixture of both natural land-cover (e.g. bare ground, water, vegetation) and man-made or impervious land-cover (e.g. roads, buildings). The distribution of land-cover classes is important for environmental management, disaster management and urban planning. There have been many researches focusing on the classification of vegetation in agricultural lands or forests. However, researches on the classification of man-made land-surfaces in urban areas are still limited due to their high complexity. Owing to the fine spectral resolution, hyperspectral remote sensing data have potential to classify artificial land-cover with different materials. Hyperspectral remote sensing technology has advanced significantly in the last few decades and its overview is provided in literature [1, 2]. Several airborne and spaceborne instruments with over 200 spectral bands have already been developed and actually in use. Since hyperspectral imaging provides many narrow-banded images simultaneously, the acquired data should be compared with the spectral reflectance characteristics of surface materials from spectral library or by field observation [3].

In this study, a fundamental study to classify urban land-cover and land-use was carried out using a dataset from the 2013 IEEE data fusion contest [4]. Using airborne hyperspectral (HS) data acquired by CASI-1500 imager over Houston, Texas, USA, the spectral reflectance characteristics of surface materials were investigated. The HS data include 144 spectral bands in the visible to near-infrared (380 nm to 1050 nm) regions. A multispectral (MS) image acquired by WorldView-2 satellite was also introduced in order to compare it with the HS image. A field measurement was also carried out using a handheld spectroradiometer by the authors. The irradiances of surface materials obtained by the measurement were also compared with the digital numbers of the HS data and they showed good agreement. Finally supervised classification was conducted for the HS and MS data and their results were discussed. The results of more detailed investigation will be presented in the final manuscript.

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9244-27, Session 6

Fusion of aerial images with mean shift-based upsampled elevation data for improved building block classification

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Nowadays there is an increasing demand for detailed 3D modeling of buildings using elevation data such as those acquired from LiDAR airborne scanners. An important step towards 3D modeling is the segmentation of the spatial dataset into homogeneous regions (e.g. buildings, roads, trees, etc.) followed by the extraction of their boundaries. The various techniques that have been developed for this purpose are based either exclusively on LiDAR data or they utilize in parallel and other complementary data such as digital maps, high resolution satellite images or aerial orthophotographs.

Our dataset considers an area of Athens, Greece, and includes aerial orthophotos in the RGB color space at a spatial resolution of 20cm, a DSM generated from LiDAR point cloud with spatial resolution of 1m and elevation resolution of 20 cm and a DTM at a spatial resolution of 2m. The normalized DSM (nDSM) is computed by subtracting an upsampled (through nearest neighbor interpolation) version of DTM from the DSM. Next, the normalized DSM is fused with the high resolution optical data in order to increase its resolution to that of the orthophoto.

The proposed methodology can be described as a two-step approach. First, an initial upsampling using the typical nearest neighbor interpolation technique is applied on the low resolution elevation data (nDSM) to obtain a low quality, ragged, elevation image. Next, in order to increase the quality of the result and eliminate the staircase effects of nearest neighbor upsampling near elevation discontinuities, we perform a mean shift-based discontinuity preserving smoothing on the fused (optical and elevation) data. The outcome is on the one hand a more homogeneous RGB image, with smoothed terrace coloring while at the same time preserving the optical edges and on the other hand elevation data with considerable improvement regarding region filling and “straightness” of elevation discontinuities. Hence, the effect of this step is to use the high detail content of the color image as a guide for improving the quality of the elevation image (see Fig. 1).

Besides the apparent visual assessment of the increased accuracy of building boundaries (compare Fig.1(b) with Fig. 1(d)), the effectiveness of the proposed method is demonstrated using the processed dataset as input to the following supervised classification methods: Feed Forward Neural Net, Cascade Forward Neural Net, Radial-Basis Functions, Support Vector Machines and Learning Vector Quantization. The performance of each method is evaluated using a subset of the test area as ground truth. The results are shown as segmented images, accompanied with a variety of statistical measures (confusion matrix, kappa coefficient, overall accuracy, Intersection over Union).

Comparisons with classification results obtained with the original unprocessed data demonstrate that preprocessing the input dataset using the mean shift algorithm improves

significantly the performance of all tested classifiers for building block extraction.

9244-28, Session 6

The extraction of buildings boundaries of the satellite imagery based on a new curvature estimation method

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One of the most important elements in the building modeling is accuracy building boundaries. The automatic building boundaries extraction is a challenging problem due to variability of building shape and the complexity of building environment surrounding.

Generally, we can divide building boundaries into two sets including straight line boundaries and curved boundaries. There are several methods in order to extract building boundaries such as Hough Transform and Randomized algorithms. For optimization of such methods it is possible to apply several algorithms which start with filtering the noise which yields to improve the image. In addition, follows to the edge detection methods to extract edge points based on image gradient.

One of the most common filters for noise reduction is Gaussian filter. Since this filter not only effects on the noise of the image, but also make the edges more smooth and softens them. To keep the information of the edges fixed, it is more practical and recommended to use Bilateral Filters which is a combination of range domain and special domain.

Having a review on the recent method, it is clear that the leakage of the presented methods such as Ransac and Hough Transform is that they are not fully automated in recognizing the areas. It means that the user has to first separate the curved and un-curved areas by own. We try applying and combining the mathematical methods to solve above problem considering the concept of Curvature to extract the edges and classification the edges with the application of Hough Transform method and optimize the edges.

In the simple object such as circle the curvature parameter of whole area is the same but in the complex shapes such as buildings, the boundaries have different shapes, so curvature estimations in different point can different.

In the proposed method, in order to improve curve detection and suppress the noise, a preprocessing step with statistical differencing method is used. Then the curvature is computed by convolution of image with the corresponding derivatives of Gauss function. According to the Gauss function which depends on blurring parameter, it is proposed to compute the accurate curvature with adaptive scale.

Obviously the results of this step contain the straight and curved boundaries. In order to exclude from the consideration impossible line positions and speed up the algorithm, a low pass curvature filter is used to delete the points of line with low curvature. After Edge curvature estimation, calculation of circle parameters must be possible. For this purpose, the edge points are clustered into subsets belonging to the different circles. To cluster edge points, modified Hough Transform is used. Then for each of clusters circle parameters can be obtained with RANSAC based.

In order to analyze the performance of proposed algorithm for extracting building boundaries, Ortho-rectified panchromatic images of WorldView-2 satellite is employed. These images are affected by illumination, shadow and occlusion. Therefore the height changes of building boundaries are useful where there is a shadow or a connected object into the building with different height. In this reason, Digital Surface Modeling (DSM) which is generated by a fully automated method of dense image matching based on minimization of total variation by convex optimization as additional dataset is used.

The proposed method is compared with combined Canny edge detector and Hough Transform method. The obtained results are showed the dividing of edge points into the subsets which help to decrease the false edge detection. Also in areas which have no information from curvature estimation adding the Canny points information can be helpful to improve this method.

9244-29, Session 6

Urban road extraction based on shadow removal and road clues detection from high resolution RGB aerial image

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In urban areas, there are a lot of objects such as buildings, cars, trees, and parks, etc. that make a complex texture or patterns in the image. Moreover, the shadow cast by buildings, and trees along the road make the road extraction even harder if we use a traditional segmentation approach. Fortunately, the very high resolution data (0.2-0.5m/pixel in spatial resolution) from the remote-sensing technology has been developed, and the quality of information is improved immensely. Therefore, we can see the road clues such as zebra crossings, cars, and road lanes marker in detail.

In this work, we propose a method of road extraction from a very high resolution RGB aerial image in the followings steps: Shadow removal, enhanced sobel transform, keypoints extraction based on Maximally Stable Extremal Regions (MSER), feature extraction based on Speeded Up Robust Features (SURF) and road construction based on segmentation. The experimental results show that the proposed method achieves a good result.

For shadow removal, first we employed the Otsu method to detect the shadow region on each RGB channel. The Otsu method will detect the appropriate threshold value to detect the darker regions. If all the RGB channels are detected as a dark region, then it will be treated as the shadow. Otherwise, we consider that it is not a shadow. The next step is to remove the shadow by increasing the lightness by adjusting the gamma and contrast value. The value is selected based on some pairing regions on the perimeter between the shadow and non-shadow. The matting process is then performed by Gaussian filter on the shadow edges to smooth the edges in the gamma correction image.

The next step is filtering the image based on Sobel to extract the gradient information of the image. The Sobel filter is performed in horizontal and vertical direction. Higher value of the Sobel result indicating a strong contrast exists, especially in the edges. Therefore, the low value of Sobel result should be suppressed. In order to discarding the low values of the Sobel result, we select based on the minimal distance from the coordinate (0,0) in the Sobel histogram.

In order to detect the road, first we recognize the clues of the road such as zebra crossings, cars and road lanes. For this purpose, we employ the Maximally Stable Extremal Regions (MSER) feature. The MSER can detect stable regions by incrementally steps through the intensity image. The keypoints are obtained from the centroid of the detected MSER region. The keypoints are then described by Speeded Up Robust Features (SURF), known as SURF descriptor. the SURF features descriptors from the template are then matched to the SURF features descriptors of the input image. We used Nearest Neighbor Symmetric as the matching score.

Finally, the road extraction is performed by meanshift segmentation, where the road region is identified by the matching points in the earlier detection. The meanshift method yields smooth regions, and the road can be extracted from the road object detected in the previous step.

9244-30, Session 6

Very fast road database verification using textured 3D city models obtained from airborne imagery

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Road databases are known to be an important part of the geodata infrastructure, e.g. as the basis for urban planning or organizing emergency services. Hence, mapping organizations all over the world spend high efforts to keep their road databases up-to-date. This is mostly realized by a periodic manual comparison of the database contents with up-to-date aerial or satellite images. In contrast to this procedure, for crisis events, like earthquakes or floods, immediate updates for specific areas are required to facilitate the crisis management. In such situations, the data should often be acquired and verified in a possibly short time. For data acquisition, aerial images and even videos taken by unmanned aerial vehicles are recently gaining popularity because of their low cost and easy use. But the problem of data verification is the manpower required to search through the imagery in order to find the incorrect database entries. The two-step semi-automatic approach presented in this paper was designed to tackle this problem.

The first step of the algorithm is data preparation for the automatic part of the road-net verification algorithm and for the recognizability of the model during the interactive post-processing that is needed to perform a clarification of the few remaining ambiguities and dubieties. As we will see, the automatic part of the algorithm on road detection method works much better if 3D structure has been extracted from the data. Thus, depth maps are used to acquire digital surface model (DSM) and digital terrain model (DTM). The difference of DSM and DTM is denoted by normalized DSM (nDSM) and is used for detection of building and vegetation. After building detection, we use a fast algorithm for decomposition of building hypothesis into several big polygons. This step is desirable because the 3D city models with up-to-date and clearly recognizable textures can be easily used for orientation in the unknown, possibly severely damaged terrain. As soon as the user can orientate in the terrain, interactive verification of surrounding road objects can be easily performed. It is worth to be mentioned that oblique UAV-videos is a very cheap and reliable tool to extract the textures of wall and that the texturing algorithm is rather fast if the number of polygons is not very high. The three main modules of the texturing algorithm: pose estimation (if the videos are not geo-referenced), occlusion analysis, and texture synthesis.

Given the orthophoto and the nDSM, automatic road verification is performed in the second step of the algorithm by a couple of independent methods. Each method represents a unique road model and a specific strategy. All individual methods correspond to simplified versions of state-of-the-art road verification approaches that are designed to deal with different types of roads and different context areas. Each method provides two different outputs: Firstly, a probability distribution that describes the state of a road object as either correct or incorrect, and secondly, a probability distribution that describes the state of the corresponding road model applicable or not applicable. Based on the Dempster-Shafer Theory, both distributions are mapped to a single distribution per method and per object that refers to three states: correct, incorrect, and uncertain. The distributions originating from the different methods are combined to make the approach robust for different types of roads and different context areas. Given the classification result, a human operator only needs to investigate uncertain and incorrect database entries and edit them if necessary. The interactive task is set up on the basis of the textured 3D city model, which provides an improved recognizability and interpretation of each situation. Experiments carried out with different datasets demonstrate that the proposed approach allows fast database correction by skipping approximately 80% of road objects while relying on rapidly accessible image data.

9244-31, Session 7

Noise estimation for hyperspectral imagery using spectral unmixing and synthesis

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Most hyperspectral image (HSI) processing algorithms assume a signal to noise ratio model in their formulation which makes them dependent on accurate noise estimation. The random noise in HSI is generally assumed to be zero-mean additive Gaussian noise uncorrelated with the signal. Many techniques have been proposed to estimate the noise. A very comprehensive comparative study on the subject is done by Gao et al. [2]. In a nut-shell, most techniques are based on the idea of calculating standard deviation from assumed-to-be homogenous regions in the image. Some of these algorithms work on a regular grid parameterized with a window size w, while others make use of image segmentation in order to obtain homogenous regions.

A noise estimation technique motivated from a recent HSI de-noising approach [1] is proposed in this study. The de-noising algorithm is based on estimation of the end-members and their fractional abundances using non-negative least squares method. The end-members are extracted using the well-known simplex volume optimization technique called N-FINDR after manual selection of number of end-members and the image is reconstructed using the estimated end-members and abundances. Actually, image de-noising and noise estimation are two sides of the same coin: Once we de-noise an image, we can estimate the noise by calculating the difference of the de-noised image and the original noisy image.

In this study, the noise is estimated as described above. To assess the accuracy of this method, the methodology in [2] is followed, i.e., synthetic images are created by mixing end-member spectra and noise. Since best performing method was spectral and spatial de-correlation (SSDC) originally proposed in [3], the proposed method is compared to SSDC. Experiments with synthetic HSIs were conducted. Experimental results suggest that the proposed noise estimation strategy outperforms the existing techniques in terms of mean and standard deviation of absolute error of the estimated noise. Finally, the proposed technique demonstrated a robust behavior to the change of its single parameter, namely the number of end-members.

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9244-32, Session 7

Visibility improvement of shadow regions using hyperspectral band integration

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The science of hyperspectral remote sensing focuses on the exploitation of the spectral signature of various materials to enhance capabilities including object detection, recognition, and material characterization. Image processing techniques

modified to leverage the vast bands and intensity information outperform similar techniques developed for three-channel imagery. We present an adaptive visibility improvement technique that leverages the numerous spectral bands, and thus improves the local contrast of the shadow regions in the hyperspectral image and increases the spatial resolution of the optimal number of spectral bands determined by the enhancement process. The proposed visibility improvement technique is presented in a two-stage approach: (1) Contrast enhancement in shadow region and (2) Spatial resolution improvement in the enhanced imagery. The first stage of the algorithm improves the local contrast within the image, thus eliminating shadows and enhancing the textural details of the scene. Our method begins by normalizing the bands of the electromagnetic spectrum of the raw hyperspectral image and selecting a mean spectral signature of an object as a reference. Variation in illumination can be detected through changes in the length of the vectors while spectral variability can be detected via the angle between corresponding spectra vectors. Thus, to avoid the effects of illumination variations on the visibility of objects in the scene, the spectral angle mapper (SAM) is employed, which allows the local pixel information to be insensitive to changes in illumination. However, in SAM, the closer angles between the reference spectrum and unknown spectra produce blurring in the image, thus we propose to use a boosting method on SAM to enlarge the local contrast. This can be achieved by analyzing the spectral angle derivative of the SAM image. This enables us to determine the spectral bands that enhance the local contrast within shadow regions. In the second stage, the spatial resolution of the contrast enhanced image is increased by using single image super-resolution technique on each selected band. The super-resolution technique is based on multi-level local Fourier phase features. This method uses adaptive kernel regression technique based on multi-level local covariance to estimate the high resolution image from a low resolution input. The multi-level Fourier image features are used to learn the local covariance from geometric similarity between low resolution image and its corresponding high resolution image. For each local region, four weighted integrated directional variances are estimated to adapt the interpolated pixels. Finally, the combination of the contrast enhancement and super-resolution approach provides better visibility of objects in the shadow regions. To verify the effectiveness of the proposed technique, we use the Resonon Pika II hyperspectral camera, which provides 240 spectral channels that ranges from 400-900nm with 2.1nm spectral resolution, to capture real-life images and test our algorithm in varying global illumination and shadow regions. Specifically, the proposed technique is evaluated by quantifying the effects of the algorithm on feature extraction and object detection within shadow regions of the scene. We provide a comprehensive analysis that compares the performance of the proposed technique against state-of-the-art three-channel image enhancement techniques.

9244-33, Session 7

Hyperspectral chemical agent standoff detection using sparse representation

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Standoff detection, identification and quantification of chemical agents are fundamental needs in various fields of applications. We propose a sparsity-based algorithm for standoff detection of chemical agents in conjunction with constrained energy minimization (CEM) band selection in Hyperspectral imagery (HSI). The proposed sparsity-based detection (SD) approach relies on the observation that spectral signatures belonging to the same class approximately lie in a low-dimensional subspace. An unknown test sample can be represented by only a few training samples in the structured dictionary, and the underlying sparse representation vector contains discriminative information for detection. The proposed algorithm is applicable to both spectrally pure as well as mixed pixels. Experimental results show that SD outperforms the classical detection algorithms such as generalized likelihood ratio test (GLRT), adaptive coherence estimation algorithms (ACE), and orthogonal subspace projection (OSP).

9244-34, Session 7

Subspace based non-parametric approach for hyperspectral anomaly detection in complex scenarios

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Anomaly detection in HyperSpectral Images (HSIs) has proven valuable in several applications, ranging from geology to environmental monitoring, from wide area surveillance to public safety.

The goal of anomaly detection is searching the HSI for small and rare objects (i.e., the targets) that are spectrally anomalous with respect to the background. In this regard, detection of the anomalous pixels is generally performed with reference to a statistical model of the background distribution. Very well-known examples include the RX algorithm, which assumes a multivariate Gaussian model for the background, and those global anomaly detection algorithms based on the Gaussian Mixture Model.

More recently, increasing attention has been devoted to non-parametric anomaly detection methods that, without assuming any specific model for the background distribution, seem to be particularly suitable to detect anomalies embedded in complex backgrounds. These include the detectors based on the kernel density estimator (KDE). According to this approach, the background probability density function (PDF) is estimated in a data-driven non-parametric fashion, by combining the outcome of a kernel function placed at each pixel of the image. These detectors have been shown to benefit from the flexibility provided by the KDE approach, which attempts to estimate the background PDF regardless of the specific form of this latter. However, KDE methods involve a high computational burden and, thus, KDE-based detectors have been so far applied to lower-dimensional feature-reduced HSIs. Whereas established dimensionality reduction (DR) methods exist to identify the subspace where most of the useful signal lie, it may nevertheless happen that some components of the rare anomalous targets are discarded during the DR procedure, with a subsequent degradation of the detection performance.

In this work, a novel subspace based anomaly detector is proposed that overcomes the limits of the KDE-based detectors performed on the dimension-reduced HSI. The proposed procedure exploits also the data features in the orthogonal complement of the estimated signal subspace. The new method consists of three steps. In the first step, the signal subspace (containing most of the useful signal) and its orthogonal complement (containing noise and potential target components) are estimated. In the second step, the background PDF pertinent to the signal subspace is estimated by means of the KDE, whereas the data PDF in the residual subspace is estimated assuming a multivariate Gaussian distribution for the noise. Finally, in the third step, assuming the data belonging to the two subspaces are statistically independent, the joint PDF of the background pixels is constructed by taking the product of the two PDFs estimated during the second step.

In the final paper, results obtained by applying the new procedure to real data concerning a complex scenario will be presented and discussed. An experimental comparative analysis with state-of-the-art anomaly detectors will be also presented to discuss the advantages and the limits of the proposed approach.

9244-36, Session 8

Reducing false positives in change detection

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When applying change detection using imagery the goal is to classify significant changes and minimise false negatives

and false positives. Many false positives come from changes introduced by atmospheric effects, leaning of 3D objects, illumination differences and shadow. Here 3D models are needed to model and compensate for these effects. This paper introduces a method that uses an object oriented 3d model based on Triangulated Irregular Network (TIN) with buildings at Level of Detail 2 (LoD2). Voxels are used to present individual trees. An algorithm has been developed to place 3D objects represented in an aerial image at the correct 2D positions at the ground surface using exterior parameters of the aerial image. The leaning effect is thereby eliminated, which results in a true orthophoto. Another algorithm uses the 3d objects to determine whether they are in the line of sight to the sun and cast shadows to other objects. The result is a simulation of illumination and shadow. The modelled results are then used in an object based image analysis (OBIA) methodology in which two sets of aerial images are evaluated for changes. A change to an object takes place when the simulation of the second image is incorrect. The change detection is improved by this method significantly.

9244-37, Session 8

Hyperspectral anomalous change detection in the presence of non-stationary atmospheric/illumination conditions

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Anomalous change detection (ACD) in hyperspectral imagery (HSI) is a challenging task aimed at detecting a set of pixels that have undergone a relevant change with respect to a previous acquisition. The changes of interest are those due to the insertion, movement or removal of objects between the test and the reference images.

Generally, in ACD, two problems have to be taken into account. First, the multi-temporal images are not radiometrically comparable because they are usually collected under different atmospheric/illumination conditions. This generates pervasive and uninteresting changes that must be properly taken into account in designing the ACD strategy. Second, it is difficult to obtain a perfect alignment of the two images especially when the sensor is mounted on airborne platforms. A residual mis-registration error (RMRE) is therefore unavoidable and it is detrimental for ACD algorithms aimed at detecting small changes having size in the order of the image pixel. The recently proposed local co-registration adjustment approach has been shown to be very effective to improve detection performance in the presence of RMRE.

As to the radiometric difference in the multi-temporal image pair, several algorithms have been proposed in the past to cope with this problem. Most of them assume that atmospheric/illumination conditions are spatially stationary in each of the two images and do not take into account the possible presence of shadows.

In this paper we propose a new ACD scheme based on a two steps procedure that is robust to problems related to the different (possibly non-stationary) atmospheric/illumination conditions between the two images and to the presence of shadows. In the proposed scheme, ACD is not performed directly on the two HSIs, but on two feature images extracted individually from each HSI. The feature images are extracted to guarantee the robustness to the spatial non-stationarity of the atmospheric/illumination conditions in both the HSIs. Specifically, they are obtained taking the decision statistics provided by the RX anomaly detection algorithm applied individually to each HSI. The RX statistics are invariant to linear transformations and are therefore less influenced by changes in atmospheric/illumination conditions. Moreover, RX features are computed locally and are more robust to the spatial variability of the atmospheric/illumination conditions and to the presence of shadows.

In the paper, the advantages and limits of the new ACD strategy will be discussed and the results obtained by comparing the performance of such a strategy with that of a state-of-the-art ACD algorithm on real data will be presented. The experimental analysis is carried out on a multi-temporal data set collected by a new generation airborne hyperspectral sensor during a measurement campaign specifically designed for the experimental assessment of ACD algorithms in a complex scenario.

9244-38, Session 8

A novel approach to change detection in very high resolution multisensor images

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No Abstract Available.

9244-39, Session 8

Cloud masking of multitemporal remote sensing images

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Next generation of Earth observation satellites will provide image time series with an unprecedented temporal frequency at high spatial resolution. However, satellite images can be affected by the presence of clouds, which hinder the regular exploitation of the time series to analyze the land cover dynamics at a global scale.

An automatic cloud masking is one of the first required processing steps since the operational use of satellite image time series might be hampered by undetected clouds (Gómez-Chova et al., 2007). The high temporal revisit of current and forthcoming missions allows us to consider cloud screening as an unsupervised change detection problem in the temporal domain (Hagolle et al., 2010; Gómez-Chova et al., 2012). Therefore, we propose a cloud screening method based on detecting abrupt changes in the temporal domain. The main assumption is that image time series follow smooth variations over land (background) and abrupt changes in certain spectral and spatial features will be mainly due to the presence of clouds or cloud shadows (Zhu & Woodcock, 2012; Gómez-Chova et al., 2013).

The method finds sudden changes in the image of interest that correspond to the presence of clouds by 1) taking into account specific characteristics of cloud covers and 2) using the other images in the time series to characterize and avoid common surface changes that do not correspond to clouds. The use of kernel methods allows the generalization of the algorithm to account for higher-order (nonlinear) feature relations and measure differences between images in a richer feature space. Moreover, kernel methods are particularly robust to reduced sample sizes and high-dimensional feature spaces, situations often encountered in multispectral image detection problems (Amorós-López et al., 2013). After cloud detection, this cloud-free time series at high spatial resolution can be used to obtain a better monitoring of the land cover dynamics and to generate more elaborated products.

The proposed method is tested in a dataset with 5-day revisit time series derived from SPOT-4 and RapidEye at high resolution. This dataset has been collected by the European Space Agency (ESA) in preparation for the exploitation of the Sentinel-2 mission, which will provide 5-day temporal revisit when using its constellation of two satellites together (Drusch et al., 2012). In addition, in order to handle the large data volumes that will acquire Sentinel-2 satellites, the proposed algorithms are being developed within the “Sentinels Synergy Framework” (SenSyF), where the processing chain

for Sentinel-2 data will be implemented on a dynamic parallel processing infrastructure in order to exploit the capabilities of grid computing.

9244-40, Session 8

An unsupervised approach based on Riemannian metric to change detection on multi-temporal SAR images

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Multi-temporal synthetic aperture radar (SAR) images acquired by satellites on repeat-pass orbits over the same geographical areas are increasingly applied to remote sensing applications, such as urban planning, environment monitoring and maritime surveillance. Therefore, the development of effectively unsupervised change detection (CD) techniques has great significance.

The change detections on SAR images acquired at different times are usually implemented in an unsupervised way, constituting of two steps: 1) compare two images pixel by pixel to generate a difference image (DI); 2) automatically threshold the difference image and obtain a change detection (CD) map. The ratio operator is a commonly used method to generate a DI, which depends on the relative change of the average intensities of the images acquired at two dates. In the second step, for SAR images the generalized Kittler-Illingworth (K&I) technique by taking into account the non-Gaussian distribution is used to threshold the DI. The K&I algorithm is developed based on the Bayesian decision theory for the minimum of classification errors, and the parameters of the probability distributions are estimated by using histogram-fitting technique.

Since SAR images are affected by the speckle noise with a multiplicative nature, the geometric average by using the products of the pixel values is superior to the arithmetic average. Moreover, Bayesian decision theory requires an explicit distribution being involved. When a-prior knowledge is unknown, “distance” measure can be considered as an alternative. By increasing the distance of distributions on considered classes, the classification errors can be minimized. Therefore, a Riemannian metric from the view of differential geometry defined on spectral density functions is introduced. The derived geodesic distance of the Riemannian metric provides an explicit formulation, which can be used to compare the two density functions.

This paper investigates an unsupervised approach to detect changes on multi-temporal SAR images. The proposed approach being different from the existing method is associated with the following aspects:

1) An operator by comparing the local geometric average calculated on one image with the overall local geometric average calculated on images acquired at two dates is developed to detect the changes. Then, the positive changes and negative changes can be identified effectively by using the proposed operator.

2) The changed and unchanged classes are characterized over a photometric variable, which actually estimate the shapes of the distributions for the considered classes. The difference between the distributions is measured by using the geodesic distance derived from the Riemannian metric. The optimal threshold is achieved when the distance between the two distributions is maximized.

Experiments are carried on two Radarsat-1 images with spatial resolution 6.25 m. The proposed operator was compared with the ratio operator in detecting the changes on the multi-temporal Radarsat-1 images. The thresholding technique based on the Riemannian metric performed well on the difference image obtained from the proposed operator. By comparison with the generalized K&I technique on the Nakagami-ratio distribution, qualitative and quantitative results confirm the effectiveness of the proposed technique in identifying the changes.

9244-41, Session 9

A transductive support vector regression method to estimate biophysical parameters from remotely sensed images

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One of the most important applications in remote sensing is the accurate estimation of biophysical parameters from remotely sensed images. An effective way to estimate biophysical parameters is to exploit supervised regression methods. These methods require the availability of ground reference measures (i.e., training samples) to be used in the learning phase of the regression algorithm [1]. The performance of regression methods highly depends on the amount and the quality training samples. However, in practice gathering enough reference measures can be expensive, complex and in some cases unfeasible. A possible approach to overcome this problem is semi-supervised learning (SSL) that aims to exploit both labeled and unlabeled samples in the learning of the phase of the supervised algorithm. Most of the previous studies in SSL have been developed in the context of classification problems [2], whereas this approach has been marginally considered in regression problems in remote sensing [3].

In this work we introduce a novel semi-supervised regression method to estimate biophysical parameters in the context of ?-insensitive Support Vector Regression (SVR). The proposed transductive SVR (TSVR) method is inspired from the transductive Support Vector Machine (TSVM) approach presented in [2] for classification problems and extends its use the framework of SVR. The TSVR is based on a transductive inference procedure that exploits a weighting strategy for tuning the importance of labeled and unlabeled samples in the learning phase of the SVR algorithm. This is done according to an iterative algorithm which gradually searches reliable unlabeled samples in order to better model the SVR function in the kernel space. At the initial iteration, the standard SVR is used to obtain an initial ?-insensitive tube based only on labeled samples. Then, “pseudo” target values are given to the unlabeled samples based on the current SVR function. At each of the following iterations, a subset of unlabeled samples (i.e., the transductive samples) is chosen and used to define a hybrid training set made up of these samples and the original labeled samples. The hybrid training set is used to find a more reliable SVR function with respect to the distribution of all the available samples. This is achieved based on a weighting strategy that assigns full weights to the training samples, while setting reduced weights to the transductive samples. This choice allows to reduce the importance assigned to the transductive patterns for which real target values are not existing (i.e., only “pseudo” target values are available).

Concerning the selection of transductive samples, we aim to choice the informative samples with an expected accurate target values. In SVR problems, the samples inside the ?-tube do not have any importance (i.e., role) in determining the SVR function. On the contrary, the samples outside or on the boundary of the ?-tube model the SVR function and thus are informative. The samples on or close to the boundary have the largest confidence to be correctly estimated among the informative samples. Accordingly, we aim at selecting samples that are located i) as closest as possible to the ?-tube and ii) outside (or on the boundary) of the ?-tube. This is achieved by a clustering-based procedure. In the proposed procedure, the cluster centers are initialized with the support vectors (SVs) that are located on the boundary of the ?-tube (i.e., the SVs that have Lagrange multipliers smaller than the SVR regularization parameter value). Then, all the unlabeled samples are clustered. The unlabeled samples closest to these SVs have high probability to lie close to the ?-tube. Accordingly, from each cluster, samples closest the cluster centers are selected. The number of samples being selected from each cluster is defined according to the density of clusters. As a result, samples that are associated with portions of the feature space having high density of samples are selected as transductive samples. The density of each cluster is identified by computing the ratio between the total number of samples in the cluster

and the maximum distance between the two samples having the largest distance in the same cluster. After the selection of transductive samples, these samples are included in the hybrid training set and then TSVR is retrained.

Due to the space constraints the detailed information both on the proposed TSVR method and on the proposed strategy to select transductive samples will be given in the full version of the work. Experiments are in progress on a data set for the estimation of tree parameters (i.e., stem volume and stem diameter) from a set of features extracted by Light Detection And Ranging (LiDAR) data acquired on a forest. Results will be presented in the full paper.

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9244-42, Session 9

Automatic localization of backscattering events due to particulate in urban areas

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Particulate matter (PM), emitted by vehicles in urban traffic, can greatly affect environment air quality and have direct implications on human health, visibility and historic buildings preservation. The consequences for society are relevant and can impact also on national safety. Pollutants emitted by vehicles are typically regulated by government agencies. In the last few years, the interest in PM emissions has grown substantially due to both air quality issues and the effects on global and regional radiative forcing and therefore climate change. Lidar-Dial techniques are widely recognized as a cost-effective alternative to monitor large regions of the atmosphere. To maximize the effectiveness of the measurements and to guarantee reliable, automatic monitoring of large areas, new data analysis techniques are required. In this paper, an original tool, the Universal Event Locator (UMEL), is applied to the problem of automatically indentifying the time location of peaks in Lidar measurements for the detection of particulate matter. The method developed is based on Support Vector Regression and presents various advantages with respect to more traditional techniques. In particular, UMEL is based on the morphological properties of the signals and therefore the method is insensitive to the details of the noise present in the detection system. The potential of the proposed technique is exemplified with the help of data acquired during several experimental campaigns in the field. The approach is also fully general, purely software and can therefore be applied to a large variety of problems without any additional cost.

9244-43, Session 9

A procedure to detect impervious surfaces using satellite images and Lidar data

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The detection of impervious surfaces is an important issue in the study of urban and rural environments. Imperviousness refers to the inability of water to pass through a surface. Although impervious surfaces represent a small percentage of the surface of the Earth, the knowledge of their locations is relevant to the planning and management of human activities. Impervious structures are primarily artificial or man-made constructions, such as roads (streets, motorways, and paved floors) and rooftops. Impervious surfaces are an environmental concern because many processes that modify the normal function of land, air, and water resources are initiated during their construction. For example, pavement materials seal the soil surface, eliminating rainwater infiltration and natural groundwater recharge. Furthermore, impervious surfaces collect solar heat in their dense mass, forming urban heat islands by depriving tree roots of aeration, which eliminates the canopy shade that would moderate urban climate.

This paper presents a novel method of identifying impervious surfaces using satellite images and LIDAR data. SPOT images, formed by four spectral bands (corresponding to Red, Green, Near Infrared (NIR) and Mid-infrared (MIR) wavelengths), and a .las file are the inputs for the procedure. The proposed method computes five decision indexes from the input data to classify the studied area into two categories: impervious (subdivided into buildings and roads) and non-impervious surfaces. The impervious class is divided into two subclasses because the elements that form this category (roads and rooftops) have different spectral and height properties, and it is difficult to combine these elements into one group. The five decision indexes are: the Normalized Digital Vegetation Index (NDVI), which is used to determine the location of the vegetation; the intensity value of the LIDAR data, which is used to find paved surfaces; the normalized Digital Surface Model (nDSM), which is useful in defining the height of the surfaces in the studied area; the difference between the first and last pulse height of every LIDAR pulse, which helps delimit the perimeter of man-made constructions; and an index created by the authors to identify the water surfaces, which combines the NIR and MIR bands of the SPOT image. The classification is conducted using a decision tree procedure. For every decision index, a threshold is set for which every surface is considered to be impervious or not impervious. The proposed method has been applied to four different regions located in the north (Galicia), the center (Benavente and Talavera), and south (Castellón) of Spain, providing satisfactory results for every dataset. The current procedure works at the pixel level, but in the future, a segmentation procedure for the region level will be considered.

9244-44, Session 9

A unified algorithm for ship detection on optical and SAR spaceborne images

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Historically, Synthetic Aperture Radar (SAR) is the most widely used sensor for ship detection from space. Optical sensors are increasingly used in addition of these. Capacities of maritime surveillance systems from space are directly related to the number of satellites in use and therefore the combined use of SAR and optical sensors in an operational framework becomes a major stake of the efficiency of the current systems.

The literature, already prolific for ship detection with SAR, grows more and more on the same theme with optical products. Detection approaches in both modes are often different even if some algorithms for optical imagery are based on these developed for the SAR. With the exception of false alarm sources, optical and SAR signals of a maritime scene have many similarities. A common methodological approach shall be possibly used to detect ships in these two types of data. We present in this paper such an approach.

The major constraint in the development of the algorithm is that vessels of any size in any resolution images must be detected. The analysis of the available images allows to highlight the fact that ships have a scale-dependent common signature. For any vessel, it is possible to define a scale at which the signature matches a bright localized pattern contrasting with the surrounding sea clutter. According to the literature on ship detection, this common pattern can be detected at different scales using a wavelet transform. A prescreening stage is therefore defined from this tool.

Empirical tests are carried out to define what would be the wavelet transform and mother wavelet providing the strongest response to the desired pattern. Stationary wavelet transform associated with a discrete approximation of Meyer wavelet maximizes this response in wavelet subband coefficients. For an image, the number of decompositions is defined from the resolution and size of the largest existing ship. At each decomposition level, without a preferential orientation of vessels, the three coefficients are multiplied. This product has two advantages: first, signal to noise ratio is enhanced and secondly, only one coefficient per decomposition level has to be processed at next stage. The generated coefficient is segmented by an adaptive thresholding based on local mean and standard deviation and a specific SAR and optic parameter empirically adjusted. Morphological closing is applied to the resulting binary images. The contours of each connected component are extracted from all decomposition levels and assembled in trees.

The contour trees are analyzed in a discrimination stage. For each tree, and for each contour in it, shape descriptors are produced. As long as these shape descriptors don't match ship descriptors (different for SAR and optical product), the contours are processed. If they match it is estimated that the treated tree corresponds to a ship.

A data set is used for evaluate method parameters and another one to evaluate its performance. The obtained results are reported and analyzed. They validate the ability to use the same algorithm for ship detection in both optical and SAR images.

9244-45, Session 9

An improved algorithm for extracting atmospheric motion vectors in cloud-free region from FY-2E thermal infrared imagery

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Atmospheric motion vectors (AMV) in cloud-free region can not be obtained with current operational cloud-motion tracking and water-vapor channel algorithms. The motivation of this study is to introduce a supplementary algorithm in order to work out the low-level AMVs in the clear area with FY-2E long wave, window (10.3~11.5, 11.6~12.8 ?m) channel imagery. It has been shown that the weak signals indicating water vapor in "cloud-free region" can be extracted from FY-2E long wave infrared imagery and may be used as tracers for atmospheric motion vectors. The algorithm, named as Second Order difference method, has been raised in order to weaken the surface temperature interference to the weak signals of water vapor in "cloud-free region" by means of split window and temporal difference calculations. The results from theory analysis and cases study show that this method can make up for the wind data in regions lack of cloud but rich of water vapor and comparison between the wind vectors from this method and the NCEP reanalysis data shows a good consistency.

9244-46, Session JS1

Port surveillance by using co-occurrence matrix on multitemporal SAR images

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Nowadays, a large number of SAR images over the same geographical areas can be acquired periodically. These images have been proved particularly useful in change detection (CD) applications related to environment monitoring and surveillance for both civil and military purposes. In terms of the change detections for medium-/ high-resolution SAR images, a generally accepted method is: first compare the two images acquired on the same geographical area at different times by using a ratio operator (or log-ratio operator); take an automatic thresholding technique to the ratio image to obtain the change detection (CD) map.

This paper investigates a specific application of the port surveillance. The data set is made up of two Radarsat-1 images acquired on April 24 and August 22, 2005 with spatial resolution 6.25m. The scenario of the images refers to Kanagawa in Yokohama, Japan. The scene is complex, and several changes occurred between the two acquisitions dates. The changes are mainly due to the movements of the cargo ships and containers. In SAR images with a resolution about 6m, both the containers and cargo ships can be considered as the clusters of hot spots, due to the formatted dihedral and corner reflectors of the packed containers with grounds, and the distinct scattering mechanisms on the metal surface. As a consequence, the changes found in images caused by the movements of the cargo ships and containers can be reduced to detect the significant increase or decrease of the backscattering values.

Being specific to the application of the port surveillance, an unsupervised change detection method based on the co-occurrence matrix is proposed. The labeled co-occurrence matrix (LCM) was used to detect the built-up areas in high resolution SAR images. However, several aspects show that the proposed method in this paper is different from the LCM technique.

1) The spatial FCM clustering technique is applied to two SAR images separately with three clusters involved. The obtained three classes correspond to three levels of the backscattering values. For each image, the membership values of the pixels in the medium intensity class are updated and attached either to the high intensity class or low intensity class. Finally, all the pixels are classified into two backscattering classes with a membership value.

2) The co-occurrence matrix is calculated in a local neighborhood for a pair of pixels from the two SAR images in the same coordinates. From the resulting matrix, two features are extracted, autocorrelation and energy. Note that only the elements off the diagonal are involved in the computation of features in order to highlight the change information. The extracted two features are fused by using the RIM quantifier.

3) Kittler-Illingworth (K&I) minimum error thresholding algorithm is applied to the fused feature image to acquire the final change detection map.

Qualitative and quantitative results confirm the effectiveness of the co-occurrence matrix technique in detecting the changes. When the co-occurrence matrix technique used in the change detection procedure is replaced by the grey level co-occurrence matrix (GLCM), the changes occurred between the two dates cannot be completely detected.

9244-48, Session JS2

Topography estimation using SAR image polarimetry

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No Abstract Available.

9244-49, Session JS2

A Bayesian network approach to perform SAR/InSAR data fusion in a flood detection problem

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Thresholding SAR intensity images is one of the most used methods to detect flood events and evaluate their extent [1,2]. It is based on the low backscatter response from smooth open water bodies that allows to rapidly separate flooded areas from non flooded ones by histogram thresholding [3]. However, the presence of many land cover types, each with a different spectral signature in presence of flood, often makes this method ineffective [4]. The exploitation of a set of images (such as a multi-temporal stack) seems to provide more satisfactory results in presence of such situations [4]. Moreover, the use of interferometric coherence information between images spanning the event can be shown to further help in the discrimination process [5]. Besides the remote sensing data, additional information can be used to improve flood detection. In case of flooding, distance from the river, terrain elevation, or some combination of these data can add useful information that leads to a better performance in flood detection.

In the present work, we propose a data fusion approach, based on Bayesian Networks (BNs) [6], to analyze inundation events occurred in the last years, involving the Bradano river floodplain in the Basilicata region, Southern Italy. Time series of several COSMO-SkyMed (CSK) stripmap SAR images are available over the area. For example, starting by the available CSK acquisitions, the following random variables have been considered:

• F, that is a discrete variable, consisting of only two states: flood and no flood. This is the variable that we want to estimate by statistical inference;

• the ratio R between two intensity images acquired across the event;

• the difference C between the InSAR coherence image computed on a 1-day InSAR pair straddling the event, and a coherence image computed on another 1-day InSAR pair acquired in non-flood conditions;

• the shortest distance D of each pixel from any river course.

The proposed BN approach allows to independently evaluate the conditional probabilities P(R|F), P(C|F) and P(F|D), and then to join them to infer the value P(F=flood | R,C,D), obtaining the final probabilistic flood maps (PFM).

We evaluate these PFMs through comparisons with reference flood maps, independently obtained, obtaining overall accuracies higher than 90%.

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9244-50, Session JS2

Inversion of three layers multiscale SPM model based on neural network technique for the retrieval of soil multi-scale roughness and moisture parameters

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The retrieval of information related to physical surface parameters is a major objective of many studies in remote sensing investigations. In that context, modeling radar backscattering through natural surfaces has become an important theme of research and active remote sensing and has shown its utility for many applications in hydrology, geology, astrophysics, etc.

Most traditional electromagnetic models consider natural surfaces as single scale zero mean stationary Gaussian random processes. Roughness behavior characterized by statistical parameters like the rms height s and the correlation length l has shown large variability of the correlation function. Many mathematical works dealing with natural surfaces description have shown that they are better described as self- random processes than as stationary processes.

In this study, we have used a two dimensional multi-scale (2D MLS) roughness description where the surface is considered as a superposition of a finite number of one-dimensional Gaussian processes each one having a spatial scale using the wavelet transform and the Mallat algorithm to describe natural surface roughness.

An adapted three layers 2D MLS SPM model has been used to describe radar backscattering response of semi-arid subsurfaces. The total reflection coefficients of the natural soil are computed using the multilayer model, and volumetric scattering is approximated by the internal reflections between layers. The surface reflection terms in the modified SPM model are replaced by the total reflection coefficients from the multi-layer soil surface. The original multi-scale SPM model includes only the surface scattering of the natural bare soil, while the multilayer soil modified 2D MLS SPM model includes both the surface scattering and the volumetric scattering within the soil.

A parametric analysis presents the dependence of the backscattering coefficient on multi scale roughness, soil moisture and radar parameters.

In a previous work, we have modeled radar backscattering over a two layer geoelectrical model by taking into account volume scattering where each layer was described as a multi-scale bi-dimensional surface using our multi-scale description. The radar backscattering coefficient was expressed as the sum of a surface scattering component and a volume component. We compared the Two layers 2D MLS SPM and the Three layers 2D MLS SPM.

The overall objective of this work is to retrieve soil surfaces parameters namely roughness and soil moisture related to the dielectric constant by inverting the radar backscattered signal from natural soil surfaces.

Though the relation-ship between the backscattering coefficient is non linear and the problem of retrieving parameters may be ill-posed it may be not possible to separate the contributions from different mechanisms making the retrieval of several parameters simultaneously necessary. To perform the inversion of the modified three layers small perturbation multi-scale scattering model we used a multi-layer neural network (NN) architecture trained by a backpropagation learning rule.

9244-4, Session PS

The usefulness of wavelet-based features as global descriptors of VHR satellite images

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In this study we propose for global characterization of VHR satellite image content the usage of extended set of wavelet transform based features. Wavelet transformation of an image is carried out by successive application of

low-pass and high-pass filters, which can be continued at several levels of decomposition. At each stage the image is replaced by its smoothed versions. As the result, the set of subimages is created. If standard Discrete Wavelet Transform (DWT) algorithm is used, this set (for each scale) consists of approximation image and three detail images. Detail images represent horizontal, vertical and diagonal image edges, and approximation subimage is low-pass filtered image. From any of subimages textural features based on first-order statistics may be derived, such as entropy, energy, standard deviation, skewness and kurtosis. In previous studies, wavelet energy has been often used as a textural image descriptor and other features have not been widely tested in image analysis. Facco et al. (2011) used entropy, standard deviation, skewness and kurtosis, but these features were calculated only for approximation subimages.

In presented study we used as a textural features the normalized variance, kurtosis and modulus, calculated for approximation and detail images obtained by DWT. The DWT was computed both with Haar and Daubechies D16 wavelets, to take into account both closer and further neighborhood. To assess the applicability of proposed features as content-based descriptors of VHR satellite imagery we investigated how accurately the image tiles cut from panchromatic EROS A scenes can be automatically classified to the broad land cover types such as agriculture, urban areas, water bodies, and forest. Decision trees (C5.0) algorithm was used as a classifier. Classification tree model was chosen based on training datasets in crossvalidadion procedure and classification accuracy assessed based on validation dataset consisted of images not used in training phase. To evaluate the results we compared the overall classification errors to the errors obtained in classification approaches based on other global textural image descriptors, such as Haralick's co-occurrence matrix-based features, absolute gradient-based parameters, run length matrix-based parameters, autoregressive model parameters and multifractal parameters. The classification test was done twice, using different sets of training and validation images.

When comparing the classification efficiency of different groups of textural parameters, the best results were obtained for absolute gradient-based features. Proposed textural wavelet transform-based features proved their usefulness as global descriptors of VHR satellite image content. They allowed for classification with accuracy comparable to achieved based on Haralick's co-occurrence matrix-based features. The better results were obtained based on reduced feature set selected from all calculated image characteristics. The average kurtosis of detail images of third decomposition level (calculated with D16 wavelet) was the one of three most useful classification features (together with Haralick's S(0.4)Contrast and one of multifractal parameters.

9244-15, Session PS

A ground control points sampling design method based on smallest singular value

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The geometric correction of remote sensing images is a key issue in many geomatic applications(e.g. multi-source data integration). It contains three main procedures: (1) acquisition of Ground Control Points(GCPs); (2) estimation of geometric correction model parameters; (3) image rectification. The acquirement of GCPs is a basic step in the geometric correction, and the spatial distribution of GCPs is an important factor which affects the accuracy of image correction.

In this paper, we propose a new sampling design method, called Smallest Singular Value-based Sampling (SSVS), to obtain the optimal distribution of GCPs. When the geometric correction of remote sensing imagery is performed with a 2D or 3D polynomial function model, the estimation of geometric correction model parameters can be interpreted as an estimation of regression coefficients with a Multiple Linear Regression(MLR) model, whose design matrix depends on the coordinates of GCPs. From the perspective of regression model, the design matrix of MRL needs to be optimized to obtain the most accurate regression coefficients. In this paper, it has been proved that the Smallest Singular Value(SSV) of the design matrix is inversely proportional to the upper bound of estimation errors. By choosing the optimal distribution of GCPs, the SSV of design matrix can be maximized and the upper bound of estimation errors can be minimized. Therefore, the SSV of design matrix is used as a criterion, and the objective of SSVS is to find the sample pattern that has the biggest SSV. In theory, we could evaluate the SSV for all possible sample patterns, and select the one that has the biggest value. However, in practical applications the number of possible patterns will be formidable which means that an exhaustive search over all possible patterns is impossible. Therefore, an efficient search algorithm, simulated annealing algorithm, is employed. The simulation annealing algorithm is an iterative, combinatorial optimization algorithm which is widely used in many optimization applications.

A major advantage of SSVS is that it can evaluate the upper bound of estimation errors of the geometric correction model parameters when the size of regression-residuals is known. However, the prior knowledge of residuals is useful but unnecessary for SSVS. Two experiments were carried out to test the performance of SSVS. In the first experiment, the SSVS was compared with other two sampling design methods by using TM images acquired over Changsha, China. The sampling design methods compared are Simple Random Sampling (SRS) and Universal Kriging Model-based Sampling (UKMS). The experiment result shows that the performance of SSVS is better than SRS and similar to UKMS. Unlike UKMS, SSVS can still be used without any prior information of residuals. In the second experiment, the capability of SSVS in evaluating the upper bound of estimation errors was tested on simulation images. Through Monte Carlo simulation, it's found that the upper bound of estimation errors evaluated by SSVS is appropriate.

From the two experiments, the SSVS is confirmed to be an effective GCPs sampling design method. It can be applied without any prior information of regression-residuals. Furthermore, the upper bound of estimation errors can be evaluated with SSVS.

9244-35, Session PS

Small target detection based on three-dimensional principal component analysis in hyperspectral imagery

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Research on target detection in hyperspectral imagery (HSI) has drawn much attention recently in many areas. Due to the limitation of the HSI sensor's spatial resolution, the target of interest normally occupies only a few pixels, sometimes are even presented as the subpixels. This may increase the difficulties in target detection. Moreover, in some cases, such as in the rescue and surveillance tasks, small targets are the most significant information. Therefore, it is very difficult but important to effectively detect the interested small target. Hyperspectral remote sensing images are composed of hundreds of spatially coregistered gray images, each of which is acquired in a particular spectral channel. Using a three-dimensional tensor to model an HSI data cube can preserve as many as possible the original spatial-spectral constraint structures, which is conducive to utilize the whole information for small target detection. This paper proposes a novel and effective algorithm for small target detection in HSI based on three-dimensional principal component analysis (3D-PCA). According to the 3D-PCA, the significant components usually contain most information of imagery, in contrast, the details of small targets exist in the insignificant components. So, after 3D-PCA implemented on the HSI, the significant components which indicate the background of HSI are removed and the insignificant principle components are used to detect small targets. The algorithm is outstanding thanks to the tensor-based method which is applied to process the HSI directly, making full use of spatial and spectral information, by

employing multilinear algebra. Experiments with a real HSI show that the detection probability of interested small targets improved greatly compared to the classical RX detector.

9244-47, Session PS

Methods of combining multiple sparse classifiers: application to target recognition in SAR images

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Methods of combining the classification power of multiple sparse representation classifiers are proposed in this paper.

To characterize the signals, the monogenic signal, an new 2-D analytic signal, is performed, from which three groups of augmented feature vectors are produced based on real, imagery and phase components. The resulting feature vectors are then individually fed into a recently developed framework, sparse representation based classification. More specifically, the features of training samples are utilized as the dictionary to recover the one of testing sample as a sparse linear combination of them via sparsity constraint. By searching the class whose features could result in the minimum reconstruction error, the decisions with different confidence can be drawn.To stable the inference and improve the performance, the decisions of individual classifiers are further combined by Dempster-Shafer evidence theory and Bayesian theory, where the residual that results from individual classifier defines the beliefs, and the rule of combination forms the synthetic conclusion. The proposed fusion schemes are applied to the problem of target recognition in extended operating conditions on MSTAR database. The obtained combination results are significantly better than any individual classifiers, i.e., the improvement of accuracy in 3 percentage at least is achieved. Additionally, it also outperforms the conventional algorithms, e.g., SVM and SRC.

9244-51, Session PS

Estimating urban surface component from Landsat-5 TM data using spectral index model and sub-pixel model

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Recently, growing interest in urban ecological systems promote development of urban remote sensing. Meanwhile, urban land cover features are so complex which challenges the identifying and quantifying urban land cover types. A great amount of research has been carried out on distinguishing and quantifying urban components such as impervious surface, vegetation, soil and water. The object of this paper is to examine and to compare the effectiveness of two approaches for extracting urban components from Landsat TM data based on spectral index models (including NDVI, NDBI, NDBaI and MNDWI) and sub-pixel model (including SUBPIX algorithm and SVM algorithm). The accuracy assessment was carried out using high resolution Land Use and Land Cover based on evaluation indicators including product accuracy (PA), user accuracy (UA), overall accuracy (OA) and overall Kappa coefficient (OK). Results indicated that SUBPIX algorithm produced the worst result which underestimated the selected signatures. And for spectral index models, it showed a good distinction for vegetation and water (accuracy larger than 90%) while for impervious surface and half-naked soil this method manifested a relatively weak capability (less than 86%). The SVM model yielded a better result with an OA of 94.09% and an OK of 92.12%. In addition, a hybrid method of combining SVM and spectral index model was performed and it got a best result with an OA of 98.88% and an OK of 98.5%. The results of the research suggested that SVM had better capability in handling the mixed-pixel problem especially hybrid approach of SVM and spectral index models.

9244-52, Session PS

Two-stage subpixel impervious surface coverage estimation: comparing classification and regression trees and artificial neural networks

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The paper presents accuracy comparison of subpixel classification based on medium resolution satellite images (Landsat 5TM), performed using two machine learning algorithms built on decision and regression trees method (C.5.0/Cubist and Random Forest) and artificial neural networks. The research was conducted in southern Poland for the immediate catchment of the Dobczyce Reservoir along with an adjacent area of towns of My?lenice and Dobczyce. The research area is hilly and the land use in the catchment is dominated by agriculture with numerous villages of dispersed development. The southern part of the study area is covered mainly by forests. The aim of the study was to obtain the patern of percentage impervious surface coverage, valid for the period of 2009-2010.

Imperviousness index map generation was a two-stage procedure. The first step was classification, which divided the study area into two categories: i) completely permeable (imperviousness index less than 1%) and ii) fully or partially impervious areas. For pixels classified as impervious, the percentage of impervious surface coverage in pixel area was estimated.

In order to obtain imperviousness index maps with the minimum possible error, estimation of the accuracy of models based on the results of 5-folds cross-validation using training set for C5.0/Cubist and Random Forest algorithm was performed. For C5.0/Cubist method five approaches was checked. In the C5.0 algorithm global pruning parameter was changed and, in some cases, also fuzzy thresholds were used. In the Cubist algorithm various numbers of nearest neighbors and committee members were applied. For Random Forest method also five approaches with various number of randomly sampled variables as candidates at each split was used. In order to obtain the highest accuracy of imperviousness index map based on artificial neural networks various network architectures and testing parameters were applied. In tested architectures two hidden layers (in which from 5 to 25 neurons occurred) were used as well as a learning rate and a momentum constant were changed.

Based on the results of 5-fold cross-validation carried out using C5.0/Cubist and Random Forest algorithms, approaches guaranteeing the lowest means errors in terms of training set were selected. In the case of artificial neural networks the best architecture, with respect to learning and validating set mean errors, was chosen.

Accuracy of the final imperviousness index map was checked based on validation data set, which was not used for learning and testing of classifiers. The root mean square errors (RMS) of determination of the percentage of the impervious surfaces within a single pixel were ±11.0% for C.5.0/Cubist method, ±11.3% in case of Random Forest method and ±12.6% using artificial neural networks. Further results analysis shown, that in intensively urbanized areas C5.0/Cubist and Random Forest gave comparably good results. The aproximation of imperviousness index obtained using artificial neural network was a little worse with values over a dozen percent lower. In agriculture and forests areas the best results were obtained using C.5.0/Cubist method.

9244-53, Session PS

3D reconstruction of Vesta from sequence images of DAWN based on multiview dense matching algorithm

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Introduction:

Vesta is the largest differentiated asteroid that is still mostly intact today and is considered to be a model for the initial stages of planetary differentiation. NASA's Dawn mission entered orbit around Vesta on July 16, 2011 for a yearlong global characterization. One of the major goals of the mission is a global mapping of Vesta. The Dawn mission is mapping Vesta from three different orbit heights during Survey orbit (2700km altitude), HAMO (High Altitude Mapping Orbit, 700 km altitude), and LAMO (Low Altitude Mapping Orbit, 210 km altitude). From the Survey orbit (altitude ~2,700 km) the Dawn Framing Camera (FC) acquired 1,179 clear filter images with a mean image resolution of 256 m/pxl whereas from the HAMO orbit (~700 km altitude) there are 2,674 clear filter images with a mean resolution of 63 m/pxl. In both mapping phases the surface was imaged several times under similar illumination conditions, but different viewing conditions.

The precise shape of an asteroid is particularly important, because it is essential for derivation of physical properties of the asteroid and quantitative geomorphologic analysis. So, our aim is to reconstruct the 3D shape of Vesta by using the Dawn Framing Camera's sequence images.

Method:

With sequence images acquired from DAWN, the 3D topographic reconstruction of asteroid Vesta based on mutli-view dense matching algorithm is researched. Firstly, Using the geometric constraints of sequence images, the relative orientation parameters of sequence images is estimated based on sparse bundle adjustment. Then the sequence images are epipolar resampled which is essential for dense matching. Thirdly, multi-view dense image matching algorithm based on the geometric constraints of epipoar line is used to extract corresponding points and the 3D topography of Vesta can be reconstructed. In order to solve the mis-matching problem caused by the different scale and lack of texture detail, the search strategy of random K-D tree and RANSAC method with perspective model are used to detect outliers in the process of matching.

Result:

We constrained all 1,179 clear filter images acquired from Survey orbit, images with our stereo requirements (well illuminated and good stereo angle) and achieved at least triple stereo image coverage for the entire illuminated surface. In total, about 80 images were used to determine selected image tie points by multi-image matching for the setup of 3D tie points of 53,255 surface points. The tie points define the input for the photogrammetric sparse bundle adjustment where corrections for the nominal navigation data (pointing and position) are derived.

Finally, multi-view dense matching processes at full image resolution were carried out to yield about 1 million object points. The achieved mean forward ray intersection accuracy of the ground points is ±200 m, which is comparable to absolute 3D point accuracy. Finally, we have generated a 3d shape of Vesta covered approximately 80% of Vesta's surface.

9244-54, Session PS

Precise geometric correction of LANDSAT-8 images based on Kalman filter

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LANDSAT-8 is an earth observation satellite launched on February 11, 2013. It is the 8th satellite in the Landsat program. It is the latest in the Landsat series of remote-sensing satellites, which have been providing global coverage of landscape changes on Earth since 1972. Landsat series help scientists observe the world, monitor changes to the land that may have natural or human causes, and detect critical trends in the conditions of natural resources. Consequently, the satellite imagery must have a high degree of geometric accuracy. An iterative least-square adjustment process is applied when more GCPs than the minimum number (six GCPs) required by the physical model are used to process the no-system distortions. However, the requirement of a large number of GCPs is a limitation. It is difficult to identify and determine position of GCPs on the middle-resolution Landsat image accurately through a map or ground investigation.

The Kalman Filter algorithm was developed by Rudolf E. Kalman around 1960. The approach was designed to provide an efficient recursive solution to estimate the state of a process, in a way that minimizes the mean of the square error. The technique has numerous applications. A widely application is for guidance, navigation and control of aircraft and spacecraft in time series analysis. In this paper, the systematic correction image, GCPs, were combined with the systematic correction model to estimate the errors of the position, velocity and attitude of the satellite. A Kalman Filter algorithm was used for the optimal estimation.

The precision correction algorithm was developed to improve the accuracy of the systematic image. The correlated GCP from Global Land Survey (GLS) 2010 that were matched to systematic images were used to estimate the precision values of the orbital and attitude parameters. The parameter estimation module consists of a Kalman filter and the Light of Sight (LOS) model (scanning and orbit geometry). The estimated parameters result in the refined information of the satellite and the precise LOS model. The precision corrected images were generated according to the precise model.

The method was applied to the LANDSAT-8 Operational Land Imager (OLI) systematic corrected image as Fig. 2(a) shown. The time of initial scan of the image was September 1, 2013 02:55:18 and covered 37.287°- 40.628° N, 114.765°-117.779°E, respectively. The experiment results show that precision geometric correction based on Kalman Filter reduce the dependence on the number of GCPs when comparing to the traditional least-square iteration method. A few GCPs are enough for the correction in the purpose of precision mapping for LANDSAT-8 images.

9244-55, Session PS

Detection and imaging of the moving target using frequency space-time adaptive processing and Fractional Fourier Transform

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Synthetic Aperture Radar(SAR) is widely used in military and civilian fields, and Ground moving target detection(GMTI) by multi-channel SAR has been a focus research field. Traditional methods for multi-channel SAR-GMTI are Displace Phase Center Antenna (DPCA), Along-Track Interferometry (ATI) and Space-Time Adaptive Processing (STAP). Among them, STAP is the most useful algorithm for detecting slow moving target in stronger clutter. S. Barbarossa proposed a method using space-time filter in Doppler domain for clutter suppression and Wigner-Ville Distribution (WVD) for parameters estimation of the moving target. This method can detect and image moving target, but WVD produces cross-term interference when several moving target appear. J. Ender analysised the signal model for multi-channel SAR (MSAR), and proposed a frequency STAP method to suppress clutter which is better to suppress clutter than STAP in time domain. But the expression of the output signal after clutter suppression is not analysised and parameter estimation of the moving target is also not introduced.

In this paper, a novel algorithm is proposed for moving target detection and imaging by multi-channel SAR using frequency STAP for clutter suppression and FrFT for parameter estimation. The reference signal along azimuth direction is generated with the parameters to focus the moving target.

For SAR echo data, the slow time base tends to infinity. The Fourier transform of the data at fixed frequencies are asymptotically independent, so that the clutter can be suppressed at every different frequencies. The frequency space-time adaptive filter can not only remove the clutter completely by projecting the data into only one subspace orthogonal to the clutter subspace, but also reduce calculation amount. Fractional Fourier Transform (FrFT) is a very useful time-frequency tool and is widely used for signal processing which is very suitable for signal detection and parameter estimation, especially for chirp signal.

Based on Ender' result, this paper deduces that the result after clutter suppression by frequency STAP is a chirp signal which is the signal of the moving target. The parameters of the chirp signal is related to the moving parameters which includes target position, radial velocity, azimuth velocity. The processing steps of the proposed method are as follows. Firstly, transform the data after range compression along azimuth direction into Doppler domain, and use frequency STAP to suppress the clutter at every different frequencies. Secondly, transform the result after clutter suppression into time domain, and use FrFT to estimate the parameters of the output chirp signal. Thirdly, estimate the parameters of the moving target, and generate the azimuth reference signal to focus the moving target.

To demonstrate the effectiveness of the proposed method, simulations are provided. In this simulation, signal clutter ratio is -40dB, so that the moving target cannot be focused by traditional SAR imaging methods. But after the frequency STAP, the signal of the moving target appears clearly. By using FrFT, the parameter estimation error is less than 0.1m/s, and the moving target is focus very well.

9244-56, Session PS

A fast 3D image simulation algorithm of moving target with scanning laser radar

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Scanning Laser Radar has been widely used in many military and civil areas. Usually there are relative movements between the target and the radar, so the moving target image modeling and simulation is an important research content in the field of signal processing and system design of scan-imaging laser radar. In order to improve the simulation speed and hold the accuracy of the image simulation simultaneously, a novel fast simulation algorithm is proposed in this paper. Firstly, for moving target or varying scene, an inequation that can judge the intersection relations between the pixel and target bins is obtained by deriving the projection of target motion trajectories on the image plane. Then, by utilizing the time subdivision and approximate treatments, the potential intersection relations of pixel and target bins are determined. Finally, the goal of reducing the number of intersection operations could be achieved by testing all the potential relations and finding which of them is real intersection. To test the method's performance, we perform computer simulations of both the new proposed algorithm and an literature's algorithm for six targets. The simulation results show that the two algorithm yield the same imaging result, whereas the number of intersection operations of former is equivalent to only 1% of the latter, and the calculation efficiency is increased a hundredfold. The novel simulation acceleration idea can be applied extensively in other more complex application environments and provides equally acceleration effect. It is very suitable for the case to produce a great large number of laser radar images.

9244-57, Session PS

Compressive sensing imaging through a drywall barrier at sub-THz and THz frequencies in transmission and reflection modes

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In this work, we demonstrate imaging using sub terahertz radiation in both transmission and reflection modes through a drywall. In both modes the image is spatially discretized using metal apertures to demonstrate the technique of compressive sensing. The purpose of this work is to reconstruct the image of an object obstructed by a drywall, by sampling at a rate below the Nyquist limit. The reason for looking at both reflection and transmission cases is to examine the effect of noise and to develop an algorithm and a method to eliminate this noise in both cases. In the experiment, the imaging is accomplished by obtaining a reflection and transmission pattern of a sample letter R, which is cut from aluminum sheet of 0.2 mm thickness. Virginia Diode Instrument (VDI) sources at 118GHz and 345 GHz are used as the sub-THz and THz frequencies signal sources. Transmitted signals are amplitude modulated via power supply switching and the received signals are measured via a Golay Cell (Tydex TC-1T) and lock–in amplifier. The 10 x 10 random array patterns are fabricated by a 40kHz repetition rate pulsed fiber laser with 0.5mJ average pulse energy and 25 kW peak power per pulse (Fiberlast NanoMark 20W). The pixels have dimensions of 3x3mm.

In the reflection mode setup the source is collimated via a 5cm diameter F#2 Teflon lens, and then the letter R is placed behind the drywall which is mounted at 45o alignment with respect to the lenses and the matrix pattern. The distance between the detector and the matrix pattern are set to about 50 cm to prevent diffractive effects.

In transmission mode the same elements are used but are aligned on a straight line and the side of the drywall with letter R faces towards the receiver.

We demonstrate that the system and the algorithm are successful in obtaining the image of the letter R in reflection mode and show that out image can be reconstructed with only 40 masks out of the total 100 masks, hence demonstrating the usefulness of compressive sensing imaging techniques. Future work will be focused on examining the effect of drywall on noise and eliminating this noise by using image processing.

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9244-58, Session PS

Spatial sampling considerations of the CERES instrument

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The CERES (Clouds and Earth Radiant Energy System) instrument is a scanning radiometer with three channels for measuring radiances from the Earth. At present CERES models are operating aboard the Terra, Aqua and Suomi/NPP spacecraft and a CERES instrument will fly on the JPSS-1 spacecraft. A successor of CERES is planned for the JPSS-2 and follow-on spacecraft.

CERES scans from one limb of the Earth to the other and back. The footprint size grows with distance from nadir simply due to geometry. This growth of the footprint results in an increase of the smallest features which can be resolved from the data and an increase of spatial sampling errors. This paper presents an

analysis of the spatial sampling errors of the CERES instrument.

Spatial sampling errors are evaluated in the Fourier domain, so that the Earth scene which is viewed is represented in terms of a Fourier series. Spatial frequencies the size of the footprint and smaller are attenuated by the measurement, resulting in blurring errors. The measurements are sampled every 0.01 sec., which for the spacecraft altitude of Terra and Aqua and the scan rate of CERES, provides measurements at 7.8 km spacing in the cross-track direction near nadir. As the instrument scans from nadir, the spacing increases. This spacing is the Nyquist limit in the scan direction. The scan back and forth is completed every 6.6 seconds, so that the scan lines are separated by 25 km, which is the Nyquist limit in the along-track direction. Spatial features shorter than the Nyquist limit cannot be retrieved from the data. Moreover, these features can appear as spurious features longer than the Nyquist limit, that is, as aliasing errors. There are three causes of spatial sampling errors: blurring, aliasing and the wavelengths which are shorter than the Nyquist distances and cannot be retrieved.

The response of the instrument to a given wavelength is its system transfer function TF. The point response function is the Fourier transform of the TF. The mean-square amplitude of a wave is its spectral power. These spatial sampling errors can be computed in terms of the system transfer function, the spectral power and the spacing of the data points.

As the instrument scans from nadir toward the limb, the distance between data points and the size of the footprint increases. The larger footprint results in greater blur errors. The increased overlap of the footprints in the along-track direction reduces aliasing errors. Also, the increased spacing in the scan direction causes the spectral power which cannot be retrieved to increase.

The effect of spatial sampling errors in the application of the data for scientific research is discussed. For gridded data products in 1 degree by 1 degree regions, there is very little effect except near the cut-off of the swath of data at 70 degree view zenith angle, where the size of the footprint is comparable to the size of the grid box. For these cases the map which is created from the gridded data is blurred near the cut-off of the swath.

9244-59, Session PS

Analysis of discriminants for experimental 3D SAR imagery of human targets

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DRDC Ottawa has been investigating 3-D through wall synthetic aperture radar (SAR) imaging from an experimental high resolution L-band through-wall SAR prototype. The side-looking radar is truck-mounted with data collected as the vehicle is driven past the front of a building of interest. Tools and algorithms for 3-D visualization are being developed to exploit the resulting imagery. The through-wall technology and data exploitation algorithms and tools have the capability to enhance situational awareness for military forces operating in an urban environment. Current work involves analyzing signatures of human targets behind a wall and understanding the clutter and multipath signals in a room of interest. In this paper, a comprehensive study of the characteristics of free space target signatures is presented using 3-D SAR data from this system. The aim of this investigation is to gain a better appreciation of the signatures of targets which can later be placed behind different wall materials and to identify features for discrimination of the human target from other targets. An analysis of potential discriminants is provided.

Targets used in this investigation include a human standing with arms resting at its side, a human standing with arms stretched out, a chair, and a table, all at 10m in range with reference to the truck-mounted radar system at closest approach, and a metallic plate at 5m in range. The effects of a squinted SAR geometry on the target signatures are also investigated by comparing these results to those for the no squint case.

Six features are investigated as potential discriminants and five of them are identified as good candidates. All of the discriminants measured or calculated in this paper rely heavily on the pixel at maximum intensity (PMI) at the location of the target of interest. Five different discrimination approaches are identified as showing great potential of features that could be used to discriminate the human target from all others: PMI elevation coordinate, PMI intensity, 3dB width in azimuth of the no squint case, and the number of resolution cells in range. Based on the free-space scenario and the different targets in this study, no single feature could be used to fully discriminate the human targets from all others. A combination of at least two different features is required to achieve this.

This study will be continued to search for more features and will be enlarged to include more targets in different orientations as well as more exemplars of the human target in various positions in order to create a robust strategy for detection and classification of human targets. The research will be expanded to include an investigation of how the signatures of targets vary as they are moved behind different types of walls. Furthermore, a thorough understanding of the clutter and multipath present behind walls are required if the signature of the human target is to be extracted and discriminated from these noise sources. Eventually, efforts will be made to choose the most effective classifier for the discrimination of human targets from all others.

9244-60, Session PS

Infrared radiation scene generation of stars and planets in celestial background

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The infrared radiation characteristics of both stars and planets are of great importance for target detection and recognition in celestial background. Calculation of their positions and radiative flux are two major tasks in generation of infrared radiation scene. The radiative spectra of planets are obtained based on the blackbody assumption, while the radiative spectra of stars can be calculated using the radiation values recorded in the star catalogues or a spectral template. Although higher accuracy can be achieved from the star catalogues, its spectral is strictly restricted in a specific region. With the spectral template, the radiation values can be obtained in arbitrary spectral region with low resolution and deviation from real radiometer measurement. To improve the resolution and accuracy, an improved spectral template technique is proposed in calculating the radiation of stars. At first, with a proposed radiometric frame correction, the nonlinear distortion in SWS spectra measured by infrared astronomy satellite ISO is corrected, and the high workload and artificial error in Engelke power function is improved. Then a normalized spectral template library was established based on the corrected SWS spectra and stellar atmosphere model database ATLAS9. At last, the infrared spectra for arbitrary stellar is achieved by multiplying its Engelke function with the established spectral template.

To generate an infrared radiation scene of stars and planets which represents the realistic celestial background, the procedure is given as follows. Firstly, the coordinates of stars at initial time recorded in the star catalogues is converted into geocentric coordinates at the given observing time and place, as well as the coordinates of planets obtained by Secular Variations of the Planetary Orbits(VSOP) 87 theory. According to the sensor parameters, the coordinates of stars and planets in the field of view are projected to the imaging plane. Secondly, the irradiance of planets is calculated based on the blackbody assumption. And the irradiance of stars is calculated using new spectral template technique. Finally, an infrared radiation scene is generated with the corresponding irradiance of planets and stars at the projected locations in the sensor FOV.

The paper is scheduled as follows. After a brief introduction of research status in Section I, the general flow chart of

generating the infrared radiation scene is given in Section II. In Section III, the procedure to achieve the coordinates of stars and planets is discussed. The steps to get the radiation of stars according to new method of spectral template are illustrated in detail in section IV. Finally, section V presents results with analysis. The results demonstrate that the spectral resolution of stars is enhanced with improved spectral template technique. Moreover, the deviation between calculated spectra and radiometer measurement is obviously reduced.

9244-61, Session PS

Sub-surface based fusion experiments using ETM-8 and ERS-1 data for geological exploration

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Multispectral optical data are sensitive to the physical properties of the ground objects and express their spectral features. While SAR data are more influenced by the geometric properties and express backscatter information. Therefore, this study demonstrates the integration of Landsat ETM-8 and ERS-1 data for improved information, more specific inferences and increased interpretation capabilities. Since SAR images are affected by speckle, some standard speckle reduction filters like Lee-Sigma, Frost, and Gamma-Map were compared. Our focus was on the impact of the fusion on enhancing subsurface features for geological exploration. The fusion was performed using different algorithms namely; Intensity–Hue–Saturation (IHS), Multiplicative Transform (MT), and Gram Schmidt (GS). The experimental results showed complementary spatial and spectral resolution characteristics. The joint processing contains the details beneath the surface cover of the respective ERS-1 data while maintaining the basic color content of the original ETM-8 data. The fused images have potentially enhanced subsurface features such as structures, paleo drainage, several deposits, and reveals the fluvial features which are not observable in the ETM-8 image. In addition to the visual interpretation, the performance of each method was further quantitatively analyzed by applying the following three measures: The High Pass Correlation Coefficient (HPCC), the Root Mean Squared Error (RMSE) and the Structural Similarity Index Measure (SSIM) which depicted that the Gram Schmidt (GS) method gives the best synthesized results and outperformed the other methods.

9244-62, Session PS

Intermediate grouping on remotely sensed data using Gestalt algebra

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Human observers often achieve striking recognition performance on remotely sensed data unmatched by machine vision algorithms. This still holds true for pictorial data for which the human perceptual apparatus was not meant, such as thermal images (IR) or even synthetic aperture radar (SAR). It is reckoned that intermediate grouping mechanisms give a major part of these capabilities. Psychologists refer to these capabilities as Gestalt perceptive skills. Though these parts of the visual system are being investigated by psychologists and machine vision experts for more than a hundred years, little of their insights have found their way into systems practically applied in remote sensing. Among the mathematical structures proposed for perceptual grouping – such as production systems, tensor voting (following Medioni), or the Desolneux theory – recently a new formalism has been put forth: The Gestalt Algebra.

Gestalt Algebra gives operations for mirror symmetry, continuation in rows and rotational symmetric patterns. Each of these operations forms an aggregate-Gestalt of a tuple of part-Gestalten. Each Gestalt is attributed with a position, an orientation, a rotational frequency, a scale, and an assessment respectively. Any Gestalt can be combined with any other Gestalt using any of the three operations. Most often the assessment of the new aggregate-Gestalt will be very bad – i.e. close to zero. Only if the part-Gestalten perfectly fit into the desired pattern the new aggregate-Gestalt will be assessed very well – i.e. with value one. Certain deformations are tolerated giving sub-one assessments. There is no unity element or invers in this algebra. But the structure is suitable in both directions:

1) Successively decomposing terms into ever more complex terms means rendering an organized symmetric mandala. To this end the resulting set of primitive Gestalten must be somehow visualized in a picture.

2) Successively composing terms, and with it searching for maximally assessed Gestalten means recognizing deep hidden visual relationships between meaningful parts of a picture. To this end the primitives must be obtained from the image by some key-point detector or other appropriate filter and a threshold. It is also possible to guide the operations by including additional information such as various descriptors – e.g. the well-known SIFT descriptors or spectral properties. Intelligent search strategies are required for this direction, because the combinatorial nature of the approach may cause high computational efforts.

The contribution at hand gives the definitions and formalisms of the structure. References to related literature are listed including competing approaches for Gestalt grouping. Also, exemplarily, maximal assessed Gestalten found in selected aerial images as well as in IR and SAR images are presented. The results are reasonably well in accordance with human perception. This theory is quite young, so that some theoretical issues remain open for future research. Also some more practical issues are discussed that - for the moment - are an obstacle to embedding in state-of-the-art machine vision systems: The high computational effort, and the interface to higher order machine vision.

9244-63, Session PS

Building recognition based on big template in FLIR images

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1. PURPOSE

Building is a kind of common and significant target at the field of target recognition. With regard to the detection of particular buildings from forward-looking infrared (FLIR) images over complex ground scene, template matching is a type of sound methods. Existing means of template matching are focusing on the match between template of single surface feature and real-time image, while few algorithms refer to big template involving couple of ground features. Big template is a set of small templates which contains a great number of information of surface features, such as rivers, roads, coastlines and so on. Its information content cannot be matched by any small template and coverage area overtops one or a small amount of real-time images. Big template is by construction possessing advantages exceeding common small template, plentiful information of features can enormously enhance the robustness of matching and it has advantages in conquering noise interference or incompleteness and avoiding erroneous judgments. On account of its outstanding superiority, our purpose is to provide a method based on big template to detect targets accurately.

2. METHODS

The algorithm can be summarized as follows:

1) Extract region of interest (ROI);

2) Create similarity measurement;

3) Optimal parameters selection criterion.

In the first step, we make big template based on support data which consists of digital surface model (DSM) and visible light

projection image. From the former, buildings are selected and from the latter, we choose features such as rivers, bridges, lakes, etc. After it, distance transformation technique is used to the big template so as to eliminate uncertainty. At the same time, contour of real-time image is extracted by Canny operator. Then, big template and contour are matched by a fixed step length to create matching correlation matrix (MCM). ROI is consisting of local maximums of MCM and their neighborhoods. Here ROI is the potential area of matching points.

In the second step, we define three criteria refer to template and based on the shape properties of buildings we choose corners and their neighborhoods of template as a kind of similarity descriptor. Then, corners are detected and magnitudes and phases of their neighborhoods are obtained, absolute differences of phases between template and real-time image are calculated, mean corner response function is designed based on normal distribution of absolute differences of phases weighed by magnitudes. At the same time, overlap ratio function is designed. Finally, we create similarity measurement by multiplying mean corner response function and overlap ratio function.

In the third step, we prepare to select optimal parameters and the main ones are distance transformation coefficient (R), quantity of local maximums of MCM selected for ROI (N), matching step length (B). R is bound up with MCM and it can affect accuracy rate to some extent. N and B are two factors of quantity of matching points of ROI and can affect matching time directly. We discover the relationship between them and provide a criterion of optimal values selection of N and B. It is proved to be valid.

3. RESULTS &CONCLUSIONS

The experimental image data makes up of 21 groups of image sequences and contains nearly 14 thousand frames (320x256?8bit) and the sizes of big templates are 702x302 and 640x256, the accuracy rate of construction target recognition is about 95%. It takes about 5 seconds to process one image and it's quite short for such big template. Whether the target is in current image or not, the algorithm proposed can ascertain its location. It can also effectively overcome problems such as shelter and noise disturbance. It offers a good flexibility and accuracy in automatic recognition of buildings in FLIR images.

9244-64, Session PS

Real-time moving ground target detection algorithm based on Gaussian mixture model

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The study of moving target detection has high research value and wide developing perspective, many useful algorithms have been presented. Currently the existing moving target detection methods can be concluded into three kinds: frame differential method, background extraction method, and optical flow method, but each of them has its two sides. Considering of real-time detection of typical moving ground targets, a novel algorithm is proposed, which is based on background estimation via using Gaussian mixture model and reference background frame updating. Firstly the image grays of the target and background are supposed to obey Gaussian distribution, then the whole image can be regarded as to obey mixture Gaussian distribution which is composed of three Gaussian distributions, afterward background estimation based on mixture Gaussian model is processed, so that the reference background image can be formed. Finally detection results can be obtained via subtracting the reference background image from current frame image including targets. At the mean time the reference background image is updated with time to keep the adaptability of the background image. In order to ensure the real time performance of the algorithm, background is not updating each frame, but use the way of adaptive adjustment according to the time requirement to update the reference background when the gray difference between the reference and current image is large. Experimental results show that the proposed algorithm is effective for moving ground targets such as vehicles.

9244-65, Session PS

Reducing the complexity of the CCSDS standard for image compression decreasing the DWT filter order

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The purpose of this work is to explore different wavelet filter banks for the CCSDS standard for image compression for lossless and lossy compression. The filters explored herein were selected under the constraint of decreasing the computational complexity of the actual filter bank utilized in the CCSDS, a Couhen-Daubechies-Feauveau biorthogonal 9/7 filter bank for lossy compression and a 9/7 integer-to-integer wavelet transform approximation for the lossless case. Another constraint for determining those filters was the existence of symmetry in the filters. The latter is desired for the sake of symmetric extension compatibility of the image. Although this strategy works fine for float wavelet transforms, it is not an assured approach for symmetric compatibility of integer-to-integer wavelet approximations derived from even length filters. For the cases in which symmetric extension was not possible, it was utilized the periodic extension. The shortcoming of replacing the symmetric extension for the periodic one is that the latter does not perform as well as the former. For fair comparison between the many filters tested, the symmetric extension compatible integer-to-integer wavelet approximations were evaluated using the symmetric and the periodic extensions. Therefore, once the filters were submitted under the same conditions, it was possible to evaluate the impact in performance obtained solely from the usage of different wavelets.

The performance of each filter bank was evaluated through: compression rate, number of bits per pixel (bpp) and PSNR. It was also evaluated the number of operations that each filter bank took for computing the wavelet transform in both cases, lossy and lossless compression. All results obtained were compared against the results from the standard CCSDS, with 9/7 filters.

As for the objects of test, it was utilized raw remote sensing images collected by the satellite CBERS-2B (China-Brazil Earth Resources Satellite) through its high resolution CCS camera. The tests were performed with tallies of 512x512 from the original image (2048x5828). These images were supplied by INPE (National Institute for Space Research) in Brazil. For the CCSDS standard, it was utilized the source code developed by Hongqiang Wang from the Electrical Department at Nebraska-Lincoln University, with changes being made to the appropriated functions that perform the wavelet transform.

The results obtained have shown that the filter bank built from the Deslauriers-Dubuc scaling function with 2 and 4 vanishing moments in the synthesis and analysis banks, respectively, had a performance comparable, and by times even superior, to the float wavelet 9/7 filter bank, requiring only 79% of the operations demanded by the original 9/7 wavelet, when implemented with the lifting scheme. For the integer-to-integer wavelet transform, the integer approximation of the Cohen-Daubechies-Feauveau biorthogonal wavelet with 2 vanishing moments in both filter banks have shown a performance close to the integer-to-integer wavelet suggested in the standard, but with the number of operations decreased by 1/3.

9244-67, Session PS

Band selection of hyperspectral images using a classifier ensemble based on GA-SVM

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Hyperspectral data enables better discriminations among different complex land cover classes. However, the large number of spectral bands, but limited availability of training samples can become a curse in terms of classification accuracy, i.e. the Hughes phenomenon. Therefore, more sophisticated classifiers like Multiple Classifier Systems (MCSs) are needed. MCS is a machine learning concept that combines different classification algorithms or variants of the same classifier (classifier ensemble) to improve classification accuracy in comparison to a single classifier. Each classifier in the classifier ensemble must be as independent as possible because combining several identical classifiers would produce no gain.

It is proved that if the average error rate is less than 50% and the component classifiers in the ensemble are independent in the production of their errors, the expected error for that example can be reduced to zero as the number of classifiers combined goes to infinity. However, such assumptions rarely hold in practice.

This paper addresses a hyperspectral band selection procedure using a classifier ensemble that is based on genetic algorithm (GA) whose fitness is evaluated by an accuracy assessment tool applied on SVM classifier.

Due to the high correlation among considerable number of the bands, to perform such uncorrelated classifiers that disagree on their prediction, we first decomposed the hyperspectral dataset into a few data sources according to the similarity of the spectral bands by computing correlation matrix between them. Each source is then processed separately by performing band selection based on GA-SVM.

GA-Based band selection methods usually perform better than other heuristic search methods for large and medium size datasets. The solution space is effectively searched in parallel, which helps in avoiding local optima and relatively insensitive to noise. It, however, require considerable computation time for large data sets. For feature selection, a solution is typically a fixed length binary string representing a feature subset. The value of each position in the string represents the presence or absence of a particular feature. The algorithm is an iterative process where each successive generation is produced by applying genetic operators such as crossover and mutation to the members of the current generation.

The overall accuracy derived from the SVM classifier was used to assess the accuracy of the GA-based band selection because SVMs perform equal or better than other classifiers in terms of accuracy and are unaffected by the Hughes phenomenon.

We have considered SVM with RBF kernel in all selections and regularized its parameters by grid search strategy, a traditional method of performing parameters searching and adjusting each kernel according to the corresponding data source properties. Genetic algorithm approach is also applied for parameters regularization at the same time as band selection which significantly improves the classification accuracy.

Finally, all outputs have been used as the inputs of the final decision fusion performed by an additional SVM classifier. An integrated SVM has been also performed for all selected bands. The results of the experiments underline how the proposed GA-SVM fusion ensemble outperforms a standard SVM classifier as well as an overall GA-based band selection, in terms of accuracy.

9244-68, Session PS

Pansharpening of multispectral images using filtering in Fourier domain

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Researches on Earth resources using satellite images starts with launching LANDSAT-1 which is the first Earth observation satellite. Many remote sensing satellites had launched with technological developments after LANDSAT-1 satellite launched. Although technological developments in satellite sensors, sensors are developed in two types due to physical and technological limits. One type gives high spatial resolution images and other type gives high spectral resolution images.

A spectral resolution refers to wavelength range belongs to sensor capture that is used in remote sensing satellites. High spectral information can be obtained by capturing specific spectral bands from the electromagnetic wave spectrum. These images are called as multispectral (MS) scenes. A high spatial information means that the sensor captures sharp images with more details. These images are called as Panchromatic (Pan) scenes. Comparing with MS scenes, Pan images carry higher spatial information..

It is possible to have an image having both high spatial and high spectral resolution using image fusion, also called as pansharpening. Pansharpening process combine panchromatic and multispectral images with aim of providing an image that has both high spatial and high spectral resolution using several methods. The main idea of pansharpening of remote sensed images is based on combining spectral and spatial information from multiple images of the same coordinate based area. These results are appropriate for analyzing on post-processing on numerous disciplines such as Geographical Information Systems (GIS), Remote Sensing (RS) and various civil and military applications.

In this study, there has been examined filtering based pansharpening methods which means of using several 2D FIR filters in Fourier domain which implies that the filters were applied after taking 2D Discrete Fourier Transform of both multispectral and panchromatic image and after the pansharpening process in Fourier domain, the resulting pansharpened image was obtained with an inverse 2D DFT. In addition, these methods were compared with commonly used fusion methods which were combined as modulation based and component substitution based methods.

In modulation based method, multispectral image is been modulated by the spatial detail image of the panchromatic image while in component substitution method, the dominant component of the multispectral image in a defined transformation space is changed with the panchromatic image and applied an inverse transform in order to obtain the fused image. Brovey and High Frequency Modulation (HFM) are the examples for modulation based methods while IHS and CIELAB for component substitution based methods which were used in this study for comparison with filtering based methods.

The algorithms were applied to SPOT 6 coregistered image couples that were acquired simultaneously. Couples were chosen for three different regions which are a city image (Gebze/Turkey), a forest image (Istanbul/Turkey) and an agriculture field image (Sanliurfa/Turkey) in order to analyze the methods in different regional characteristics. These methods were compared by the fusion quality assessment methods which are Spectral Angle Mapper (SAM), Root Mean Square Error (RMSE), Relative Average Spectral Error (RASE) and Erreur Relative Adimensionelle de Synthése (ERGAS). Under each metric, each algorithm was ranked and the best competitors were identified. The results of these quality assessments shows the filtering based methods had the best scores among the traditional methods.

9244-70, Session PS

Performance evaluation of supervised change detection tool on DubaiSat-2 multispectral and pansharp images

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Supervised Change Detection Tool (SCDT) is an in-house developed tool in Emirates Institution for Advanced Science and Technology (EIAST). The developed tool is based on Algebra Change Detection algorithm and multi-class Support Vector Machine classifier and is capable of highlighting the areas of change, describing them, and discarding any false-detections that result from shadow. Further, it can collect the analysis results, which include the change of class an area went through and the overall change percentage of each class defined, in a Microsoft Word document automatically. This paper evaluates the performance of the SCDT, which was initially developed for DubaiSat-1 multispectral images, on DubaiSat-2 multispectral and pansharp images. Moreover, it compares its performance opposed to DeltaCue in ERDAS IMAGINE, Difference Change Detection in ENVI, and Optical Change in PCI Geomatica.

9244-72, Session PS

Detecting changes on coastal primary sand dunes using multi-temporal Landsat imagery

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Due to both natural and anthropogenic causes the coastal primary sand dunes, keeps changing dynamically and continuously their shape, position and extend over time. In this paper we use a case study to show how we monitor the Portuguese coast, between the period 2000 to 2014, using free available multi-temporal Landsat imagery (ETM+ and OLI sensors). First all the multispectral images are panshaperned to met the 15 meters spatial resolution of the panchromatic images. Second, using the Modification of Normalized Difference Water Index (MNDWI) and kmeans clustering method we extract the raster shoreline for each image acquisition time. Third, each raster shoreline is smoothed and vectorized using a penalized least square method. Fourth, using a Principal Component Analysis (PCA) and a supervised classification method we extract the primary sand dunes. Finally, the visual comparison of the thematic primary sand dunes maps shows that an effective monitoring system can be implemented easily using free available remote sensing imagery data and open source software (QGIS and Orfeo toolbox).

9244-74, Session PS

Geometric superresolution by using a two-dimensional orthogonal encoding mask

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In many modern optical systems, the resolution is limited not only by the diffraction caused by physical dimensions of the optics lens, but by the CCD's nonzero pixel size, especially for the traditional incoherent illumination, the restriction of CCD pixel is greater than that of optical diffraction. Here we develop a novel approach to enhancing resolution beyond the limit set by CCD's pixels, in which a two-dimensional and orthogonal encoding mask is attached before the imaging lens to modulate frequency on input target spectrum.

Here we focus on the design about a 4-f optical imaging system, considering the ability of Fourier transformation to achieve the equivalent conversion between space and frequency domain. And to prevent the loss of frequency in the overlapping regions when sampled by classical CCD, there must be some proportion between the spatial range of object plane and corresponding frequency plane. Meaningwhile, the wavefront aberration of Fourier lens needs to be controlled to fulfill the mathematical features of Fourier transformation.

We apply to improving and revising the theoretical design for the encoding mask based on the design limit of optical-mechanical engineering, and we analyze the different orthogonal forms of encoding masks which can bring the spectra diffraction to the imaging area. In this scheme, we calculate and discuss the total dimension, formation and element dimension of the encoding mask, to ensure compliance with all the optical wavelengths of project indicator. Furthermore, we consider the spectrum message based on the zero level to the second diffraction, and finally achieve the spectrum data matched to the original input object after mathematical process.

According to the theoretical discussion, revision and algorithm simulation, the results in the preliminary testing system show that the encoding mask can be used to produce enhancement of resolution by a factor of 2 in-exchange for decreasing the field of view by the same factory.

9244-75, Session PS

Spectrally consistent haze removal in multispectral data

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Water vapor, dust, fog, smoke and other components of the atmosphere can introduce haziness into optical imagery.

Haziness being uniform, thin, thick, or structured influences the VNIR/SWIR (0.3-2.2 nm) data being difficult to detect and compensate.

Appearance of haze in multispectral data reduces the accuracy of such data interpretation.

Being semitransparent, haze transmits a fraction of radiance reflected from the surface and a restoration of the propagated radiance is possible.

An efficient, fast, and automatic haze removal method handling all types of haziness is still a challenge.

This work presents an empirical and automatic method for inhomogeneous haze detection and spectrally consistent haze removal.

The dark object subtraction method is further developed to calculate haze thickness over the whole scene.

Instead of searching only several dark pixels in the whole scene the dark pixels are searched locally.

Calculation of a haze thickness map (HTM) and a proper estimation of the haze fraction per band/wavelength allows a precise spectrally consistent haze removal in many medium and high spatial resolution multispectral imagery.

The employment of any band from a multispectral image for the HTM generation can lead to overdehazing of this band.

To properly calculate the HTM an extrapolation of the multispectral data to create a new blue band is necessary.

Large objects with high reflective properties are masked and the values of the HTM in these regions are triangulated.

The haze fraction per band is estimated using a slope value in a linear regression between the HTM and an HTM calculated for a band in a multispectral image.

The haze fraction usually decreases from the lowest (blue band) to the highest (SWIR band) wavelength.

A compensation for clear scene aerosol is performed after the dehazing.

Rare scenes with a uniform highly reflective landcover result in limitations of the method.

The developed method is evaluated using hazy and haze-free reference Landsat 8 OLI data.

The hazy and free Landsat 8 data were obtained for the same area under the same Sun/sensor acquisition geometry and with time difference of one week.

A spectrally consistent haze removal is achieved on many optical sensors data such as Landsat 7/8, AVNIR 2, WorldView-2, and Rapideye.

The method can perform on calibrated and uncalibrated data.

The dehazing method can be employed separately or as a chain in remotely sensed data analysis systems.

The dehazed data can be employed for atmospheric correction, and for further processing like change detection or classification.

Future improvement of the method consists in a development of a fast triangulation procedure to handle large data volumes.

9244-76, Session PS

Quantitative method of total petroleum hydrocarbon for crude oil in soil: comparison between remote sensing reflectance data and different organic laboratory techniques. Case study, Kirkuk- Iraq

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1. Methodology

First start was study the absorption behavior for different crude oil types. The analyses of the results of Field Spec 4 - measured in Leipzig HFZ laboratories - showed absorbance peak feature with three specified wave length windows. The statistical algorithm was drifted depending on different crude oil types and its amounts with the volume and size of spectral hydrocarbon index (HI). Second step was the analyses multi source remote sensing images which ending with calculating 88 samples from typical crude oil seep with spatial resolution one sample for each 30 m to be representative for images resolution. In order to test the HI results (as depth and area by MATLAB), it was needed to compare it TPH for the soil samples. There for Total organic carbon TOC and GC/ FID were the chosen methods for TPH made in TU Darmstadt laboratories.

2. Results and discussion

The case of one phase sample (Crude oil only), it was clear to notice the differences in the absorbance peak depending on the oil density API where HI value change depending on the API oil type. The absorbance behavior with other two phase samples (oil and soil) were contain different signature, the algorithm calibrate the HI values to show real oil concentration and peak feature lead to high coefficient of determination. In order to correlate the algorithm results for field samples it was necessary to calculate TPH. Although TOC results were less relatively matching with HI, but the general linear fitting values can consider highly accepted. These differences occur because TOC with liquiTOC II measuring not just the organic material from the hydrocarbon only but also organic carbon from the vegetation even in very dry condition. For more specific results, the diction was to make farther lab method like FC/FID which still in progress. In spite of the different spatial resolution and date capturing, Hyperion satellite image for AOI with Hyper spectral resolution with similar wave length showed also unique and accepted results comparing with Field Spec 4 results.

9245-1, Session 1

Change Analysis at Stuttgart Airport using TerraSAR-X Imagery

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The detection of surface changes is a very important issue, whereby especially remotely sensed images are very helpful on demand. Different application purposes exist. Mainly in terms of disaster management and monitoring tasks, precise and fast available detection results are essential. Focusing on satellite remote sensing and in contrast to optical data, SAR imagery is nearly independent of weather constraints like fog, dust or clouds. Moreover, the time of day is not relevant which makes SAR in general well suitable for monitoring and change detection tasks.

The German satellite sensor system TerraSAR-X (TSX) offers the opportunity to acquire high resolution (HR) SAR images on a regular basis covering a large area of interest. Acquired in HS300 mode, the TSX images have a pixel spacing of less than one meter. Indeed, also small objects or objects which are placed close together can be resolved in a consistent way, the HR leads to the problem of over-representation. This over-representation refers to the fact that one semantically self-sufficient object (e.g. car) consists of many different pixels. Beside this, also the limiting effect caused by the multiplicative speckle noise make conventional pixel-based image analysis methods not suitable for being applied on such HR SAR imagery. Object-based image analysis (OBIA) methods basing on segmentations provide help and offer the opportunity to develop rule-based interpretation schemes.

In this paper, a concept of change analysis is presented. The central processing steps are represented by the detection and categorization of changes. OBIA methods are used for both the detection and the categorization section. As test area, the airport of Stuttgart (GER) and its surroundings inheriting heterogeneous possible change categories is considered.

At final state, the dataset will comprise two time series of at least ten TSX HS300 amplitude images per orbit direction. By now, nine images acquired in ascending (ASC) orbit and three images acquired in descending (DESC) orbit are available. Since time series imagery is analyzed, even seasonal or phenological effects can be observed and considered in the change categorization.

For evaluation, several reference data are available. As example, two multispectral WorldView-2 (WV-2) images acquired in 2011 and 2013 and OpenStreetMap GIS data is useable. Moreover, screenshots of webcams placed at different parts of the airport area can be utilized. This offers the opportunity to analyze reference data acquired almost at the same time as the specific TSX image. Doing so, categorized changes in these regions can be identified and evaluated. For image orthorectification, one DTED level 2 height model covering the whole test area is used.

9245-2, Session 1

SAR/multispectral image fusion for the detection of environmental hazards with a GIS

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The use of multi-sensors and multi-temporal data has emerged as a very successful approach for many remote-sensing problems. However, the integration of such data with other complex data, that are diffcult to represent verbally or sometimes even visually, plays a key role in the analysis of complex phenomena.

For these purposes, the use of Geographic Information Systems (GIS) is steadily increasing. In these systems, geographic data describing features on the earth's surface are managed, displayed, manipulated, and analysed. Moreover, the use of GIS together with digital remote sensing makes it possible to rapidly collect and analyse spatial data, yielding a powerful set of tools for the analysis of the environment.

In this paper we propose a GIS-based methodology, using optical and SAR remote sensing data, together with more conventional sources, for the detection of small cattle breeding areas, potentially responsible of hazardous littering. This specific environmental problem is very relevant for the Caserta area, in southern Italy, where many small buffalo breeding farms exist which are not even known to the productive activity register, and are not easily monitored and surveyed.

As seen from the satellite, buffalo farms are mainly characterized by the sheds and by the fenced uncovered spaces nearby used for rearing the buffaloes and for accumulating animal waste. Sheds are clearly visible both in optical images, where they have a saturated response due to their high reflectivity, and in the SAR images, where they contribute bright lines due to double reflection mechanisms. However, these responses are not at all specific, and can be confused with other highly reflective covers in the optical images (say asphalted roads) and, especially, with generic buildings in both sources. Moreover, sheds are not always close to the fenced spaces where the buffaloes live. On the contrary, the spectral signature of the manure is highly characteristic, easily discriminated from bare ground in the near infrared (NIR) band, and stable to changes in solar illumination.

Needless to say, manure is always present and abundant where the animals live, and indoor breeding is not an acceptable option. Therefore, we decided to use as main source of information the GeoEye-1 optical images, focusing on the manure signature.

In SAR images, manure does not exhibit a distinctive signature. However, we used the SAR stack to detect and mask man-made areas, thus reducing the false alarms. This is especially valuable since most of the false alarms are related to shadows projected by buildings over bare soil, which abound in urban areas due to the high density of buildings.

The maps resulting from the processing of optical and SAR images are then converted in a vectorial format and become the input of GIS-based processing, together with other available maps and with the location of farms offcially registered. The final output is a set of possible farms unknown to the productive activity register.

Experiments on a test area, with available specific ground truth, prove that the proposed systems is characterized by very large detection probability and negligible false alarm rate.

9245-4, Session 2

Simulating urban land cover changes at sub-pixel level in a coastal city

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The simulation of urban expansion or land cover changes is a major theme in both geographic information science and landscape ecology. Yet till now, almost all of previous studies were based on grid computations at pixel level. With the prevalence of spectral mixture analysis in urban land cover research, the simulation of urban land cover at sub-pixel level is being put into agenda.

This study provided a new approach of land cover simulation at sub-pixel level. Landsat TM/ETM+ images of Xiamen city, China on both the January of 2002 and 2007 were used to acquire land cover data through supervised classification. Then the two classified land cover data were utilized to extract the transformation rule between 2002 and 2007 using logistic regression. Five factors, DEM, distance to roads, distance inland water bodies, distance to sea and distance to urban centers were included in the logistic regressions as explanatory variables. The transformation possibility of each land cover type in a certain pixel was taken as its percent in the same pixel after normalization. And cellular automata based grid computation was carried out to acquire simulated land cover on 2007(Fig.1). The simulated 2007 sub-pixel land cover was testified with a validated sub-pixel land cover (Fig.2) achieved by spectral mixture analysis in our previous studies on the same date. R value was used here for validation, which is defined as the ratio of pixels whose differences between simulated and unmixed images are within [-0.1, 0.1] to the total number of pixels in the study area (Table 1). And finally the sub-pixel land cover of 2017 (Fig.3) was simulated for urban planning and management.

The results showed that our method is useful in land cover simulation at sub-pixel level. Although the simulation accuracy is not quite satisfactory for all the land cover types, it provides an important idea and a good start in the CA-based urban land cover simulation.

9245-5, Session 2

Monitoring of heat island in Shenzhen, China: using remotely sensed and ground measurements

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China, the most populous country on Earth, has experienced rapid urbanization which is one of the main causes of many environmental and ecological problems. Therefore, the monitoring of urbanization regions and their environment (e.g. heat island) is of critical importance for their sustainable development. In this study, Shenzhen city, one of the most populated cities in China, was selected to as the case of monitoring urban heat island (UHI) and surface urban heat island (SUHI) with ground meteorological measurements and Landsat 8 TIRS, respectively. Air temperature used in this study is collected by a network of 160 automatic weather stations (AWS) distributed widely over Shenzhen which has an urban area of 1991.64 square kilometer. Five Landsat 8 TIRS image acquired at 9th Aug., 19th Sep., 5th Oct., 12th Oct. and 29th Nov., 2013, were used to estimate land surface temperature through split-window algorithm and NDVI-based emissivity retrieval. Meanwhile, artificial neural network based algorithm was proposed to calculate air temperature with reflectance at red and near-infrared bands and land surface temperature. SUHI and UHI were well observed through land surface temperature and air temperature results. The spatial structure of the thermal urban environment is analyzed in each image and the “hottest” surfaces within the urban settings are identified and related to the urban surface characteristics and land use.

9245-6, Session 2

Does escape of ULF of EM radiation from solar spectrograph characterize of stress drop or the outbreak any seismic event?

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Study of solar spectrograph directly connected to satellite data of IPS or NOAA (JPL NASA) reveals generally warning for solar storm or coronal mass ejection. But at the same time investigative study of spectrograph for the period of at least ten days observation prior the seismic event significantly shows escape of certain frequency EM radiation on the spectrograph. Tenure of escape is continued at least for three hours prior the event. Duration and amount of attenuation of LF, EM radiation in the spectrograph is compensated in rising electric field following the basic electrostatics law. Maxwell theory of EM wave propagation accounts compete mechanism for the attenuation of LF of 18to 25 KHz frequency in the spectrograph and substantial rise in MMC and TEC as magnetic and electric component in the global map; from the ground to ionospheric level. The facts are supported by event of Iran 7.8 Mw on 14th April 2013 and Japan 6.7 Mw n 7th May 2013.

Images collected by real time monitoring of solar spectrograph dta by connectivity of IPS Australia, Caligula, Lear-more, and other observatory by NOAA Jpl NASA satellite have revealed important feature about escape of certain frequency of 18-25hz immediate prior the seismicity. It is understood due to compensate strain relaxation in the electric field Electronic charge developed at LIA contact are consumed in setting up and compensating THE IONOSPHERIC IONS AND tec shortage. This ionospheric protuberance is working on the principle of Maxwell theory of wave prorogation

9245-7, Session 3

Preparation of a national Copernicus-service for detection and monitoring of land subsidence and mass movements in the context of remote sensing assisted hazard mitigation

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Land subsidence processes can cause severe damage to buildings and infrastructure and mass movements can lead to loss of live. Detection and monitoring of these processes by terrestrial measurement techniques (e.g. dGPS, leveling) remain a challenge due to limitations in spatial coverage and temporal resolution. Space-borne SAR-sensors provide time series starting from 1992 (ERS-1) allowing a retrospective analysis of ground-deformation by using SAR Interferometry (InSAR). Modern SAR-sensors like TerraSAR-X or COSMO-SkyMed (operational since 2007) are characterized by a high revisit time. This strongly improves the potential for InSAR analysis by minimizing temporal decorrelation. In addition small scale deformations are able to be detected and monitored by using acquisition modes with very high spatial resolution (e.g. Stripmap mode has a resolution cell < 5 meter and a swath wide of 40 x 40 km). Since the launch of ERS-1 numerous scientific studies demonstrated the capability of InSAR for detection of land subsidence and mass movements proving the operational usability of this method. In order to assist the utilization of this method for governmental tasks a national service-concept within the EU-ESA Program “Copernicus” is in the ongoing process of preparation. This is done by i) analyzing the user requirements, ii) developing a strategy by using different scenarios and iii) creating a service-concept. Due to the iterative nature of this procedure governmental users as well as InSAR processing experts are involved and pilot studies are performed for optimizing the proposed workflow. This paper introduces the service-concept as well as one proposed pilot study. The pilot study will focus on the application of the InSAR technology for detection of vertical and horizontal surface deformations above a hydrocarbon reservoir. The area of interest is located 20 km south-east of Bremen in the state of Lower-Saxony, Germany. InSAR analysis will be based on a COSMO-SkyMed time series covering the time period from 2011 – 2014. Due to “atmospheric noise” and the heterogeneity of land cover (rural and peri-urban) the PSI (persistent scatterer interferometry) and the SBAS (small baseline subset) approach are going to be used. Both are aiming at the minimization of the “atmospheric noise” by identifying either persistent or distributed scatterer within a resolution cell based on a stack of SAR imagery. Since InSAR provides information about surface deformation in the line of sight (one dimensional), motion decomposition is intended to separate horizontal from vertical surface deformation and will be carried out by using SAR-imagery acquired from ascending and descending orbits. Subsequently the derived deformation signals will be compared with natural gas production rates. The usability of the derived deformation maps will be discussed with the responsible mining authority (LBEG) in order to iteratively adapt the workflow to the specific user needs. This way a valuable contribution for the service-concept is expected by the pilot study, particularly for steps i) and ii).

9245-8, Session 3

Landslide monitoring using airphotos time series and GIS

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Western Greece is suffering by landslides. The term landslide includes a wide range of ground movement, such as slides, falls, flows etc. mainly based on gravity with the aid of many conditioning and triggering factors. Landslides provoke enormous changes to the natural and artificial relief. The annual cost of repairing the damage amounts to millions of euros.

In this paper a combined use of airphotos time series, high resolution remote sensing data and GIS for the landslides monitoring is presented. Analog and digital air-photos used covered a period of almost 70 years from 1945 until 2012. Classical analog airphotos covered the period from 1945 to 2000, while digital airphotos and satellite images covered the 2008-2012 period. The air photos have been orthorectified using the Leica Photogrammetry Suite. Ground control points and a high accuracy DSM were used for the orthorectification of the air photos. The 2008 digital air photo mosaic from the Greek Cadastral with a spatial resolution of 25 cm and the respective DSM was used as the base map for all the others data sets. The rms error was less than 0.5 pixel. Changes to the relief and to the artificial constructions were digitized and then implemented in an ARCGIS database. The results are presented in this paper.

9245-9, Session 3

Open quarry monitoring using gap-filled LANDSAT 7 ETM SLC-OFF imagery

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Active quarries are at the same time a necessity but also a source of pollution. Necessity as they supply to the construction companies the necessary aggregates and source of pollution as they affect biodiversity, vegetation cover and threaten water resources. The objective of this work is to indicate a monitoring methodology using Landsat ETM SLC off imagery.

On May 31, 2003, the Scan Line Corrector (SLC), which compensates for the forward motion of Landsat 7, failed. Without an operating SLC, the Enhanced Thematic Mapper Plus (ETM+) line of sight now traces a zig-zag pattern along the satellite ground track. As a result, imaged area is duplicated, with width that increases toward the scene edge. An estimated 22 percent of any given scene is lost because of the SLC failure. The maximum width of the data gaps along the edge of the image would be equivalent to one full scan line, or approximately 390 to 450 meters. The precise location of the missing scan lines will vary from scene to scene.

In this study a gap filling technique for Landsat ETM SLC off imagery is evaluated. Different Landsat 7 ETM+ images SLC off were restored and then compared to historical data and data from other sensors. The technique of re-establishment is executed automatically through a flow chart and the application MODELER of ERDAS IMAGINE. Firstly, a image acquired before and an image acquired afterwards the scene under correction are selected. The gap filling technique is based on the fact that the precise locality of lines that are absent varies from scene in scene. Afterwards the histogram of previous scene is matched to that of later and a new image is created. Data from this image replaces in the initial scene the empty lines. More than 11 images covering the period 2004 - 2014 were restored. The restored images have been used in order to monitor the expansion of an open quarry in western Peloponnese and the results are presented.

9245-10, Session 3

Analysis of spectrometric optical data from different devices

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Remote sensing is a general tool to investigate the different areas of Earth and planets. The development of the implementation capabilities of the optoelectronic devices which are long-term-tested in the laboratory, in the field and are mounted on-board of the remote sensing platforms further improves the capability of instruments to acquire information about the Earth and its resources in different scales. Remote sensing application in the Earth observation begins with the design and the assembling of equipment for carrying out research of the monitored objects remotely and without disturbing their integrity. Ground-truth data in the Earth observation of the environment and in the remote sensing investigations are very important. Remote sensing methods for studying of rocks and minerals are closely related to current programs for the mineral and chemical composition study of the Earth, Mars and Phobos surfaces. The experience and the knowledge from previous experiments in space missions encourage us to continue our efforts to acquire spectral data using different remote sensing systems and to compare the obtained results. The main goal in the geological remote sensing is the determination of the chemical and/or mineral composition and the structure of the rocks. For this purpose the laboratory and the field spectroscopy measurements are performed. These measurements are made to collect, compile and complete guide with spectral characteristics of different rocks for their reliable identification and for the determination of their mineral and chemical composition. The experiments are based on major physical principles such as light scattering, absorption of light, and reflection of light in the electromagnetic spectrum. For the purpose of present paper ex-situ spectroscopy measurements of the granites and their rock-forming minerals from the territory of Bulgaria in visible and near infrared (VNIR) range of the electromagnetic spectrum were performed using following spectrometric systems: SRM, 0.4-0.82 micrometers; SPS-1, 0.55-1.1 micrometers, Thematically Oriented Multi-channel Spectrometer /TOMS/, 0.4-0.9 micrometers, all of them designed and constructed in Remote Sensing Systems Department at SRTI-BAS. The obtained spectral data are compared with similar data from different instruments for Earth observation included in the spectral libraries. They correspond to the shape of the spectral signature in the same spectral range obtained with other spectrometers. Two wavelengths were selected and were applied for the proper comparison between the data obtained by different instruments. The dependence between the reflectance values at the chosen wavelengths and the quantitative content of the rock-forming minerals was established. The achieved results proved that this methodology could be applied for comparing the spectral data from different sources. These promising results encourage us to plan the next campaigns for the field spectroscopy measurements in different regions of Bulgaria.

9245-11, Session 3

Time series satellite and ground-based data for detecting earthquake anomalies

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Earthquake science has entered a new era with the development of space-based technologies to measure surface geophysical parameters and deformation at the boundaries of tectonic plates and large faults. According to classical earthquake theory, small earthquakes should continue to grow into large earthquakes until they spread all along the fault line. The mechanical processes of earthquake preparation are always accompanied by deformations, afterwards complex short- or long term precursory phenomena can appear .Seismic events are associated with ongoing deformation along the main active geologic faults. Macro-fracturing processes are preceding by micro-fracturing phenomena which amplify strain field, with a resulting radon and other gas precursors (He, CH4, NO, Ne, Ar, and N2) anomalies in soil-gas and groundwater, geomagnetic and geoelectric fields anomalies, ionospheric perturbations, thermic land surface anomalies, sudden water-level change in some wells, abnormality of behaviour in some animals, etc.These precursors anomalies are strong indicators of the physical basis of earthquake prediction for tectonically active areas, being correlated with seismic events. Satellite time-series data, coupled with ground based observations where available, can enable scientists to survey pre-earthquake signals in the areas of strong tectonic activity. Space-time anomalies of Earth's emitted radiation (thermal infrared in spectral range measured from satellite months to weeks before the occurrence of earthquakes, radon in underground water and soil, etc.), and electromagnetic anomalies are considered as pre-seismic signals. Vrancea tectonic active zone in Romania is characterized by a high seismic hazard in European-Mediterranean region, being responsible of intermediate depth and normal earthquakes generation on a confined epicentral area.Anomaly detection is extremely important for forecasting the date, location and magnitude of an impending earthquake. This paper presents observations made using in-situ data and time series MODIS and NOAA-AVHRR satellite data for derived multi geophysical parameters (land surface temperature -LST, outgoing long-wave radiation- OLR, net surface latent heat flux (LHF) and mean air temperature- AT for some seismic events recorded in Vrancea region in Romania, which is one of the most active intracontinental seismic areas in Europe. Starting with almost one week prior to a moderate or strong earthquake a transient thermal infrared rise in LST of several Celsius degrees (oC) and the increased OLR values higher than the normal have been recorded around epicentral areas, function of the magnitude and focal depth, which disappeared after the main shock.

9245-12, Session 3

Application of ASTER and ETM-8 images data in lithological mapping of Precambrian basement rocks in Eastern Desert of Egypt

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The central and southern parts of the Eastern Desert of Egypt comprise different ophiolitic and island-arc assemblages pertaining to Precambrian in age. They include serpentinites, metavolcanics, metagabbro, gabbro-diorite, granodiorite, monzogranites, and alkali-feldspar granites. The application of different band ratios and Principal component analyses derived from both ASTER and ETM-8 images have been applied to reveal the spectral characterizations of these rocks as well as detection of the alteration zones in three areas namely; Wadi Um Gheig, Wadi Defiet, and Eqat. At Wadi Um Gheig area, in the Central Eastern Desert of Egypt, the data of ETM-8 and ASTER images have been applied in lithological mapping revealing discrimination of three varieties of intrusives including gabbro-diorite, tonalite-granodiorite, younger gabbro, monzogranites and alkali feldspar granites. On the other hand, the discriminated volcanic varieties include basic metavolcanics, acidic metavolcanic and basic to intermediate metavolcaniclastics interbanded with iron bands. At Iqat and Deifiet areas in the South Eastern Desert of Egypt, the processed data of ASTER and ETM images have been successfully applied in lithological mapping and detection of gold-bearing alteration zones and quartz veins within the island-arc basic metavolcanics. This study revealed that, the different rock units and the mineralized alteration zones exposed in the study areas have been discriminated in the produced geological maps comparing with the previous geological mapping.

9245-13, Session 4

Fusion of declassified airphotos and Landsat MSS data for old landslides detection

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In the Laboratory of Technical Geology a landslide database for the Prefecture of Achaia was developed. At first, we created a Landslide Inventory Form, recording and archived 137 landslide cases from Achaia. Afterwards, the landslide recordings were imported to the Geographical Information Systems - GIS. Additionally, orthophotos from KTIMATOLOGIO S.A. were used and high resolution images from Google Earth were occasionally used as an auxiliary tool. This method helped us to check and enrich the archive with new data about landslide areas. In order to enrich the database with historical landslides satellite data combining high spatial and spectral resolution are required. Fusion of declassified airphotos and Landsat MSS data could be a practical and cost effective solution. In this study we have used:

An orthorectified Landsat 1 MSS image acquired on 7 /9 /1972 with a spatial resolution of sixty meters.

A declassified aerial image on 24/7/1973. Declassified Satellite Imagery consists of approximately 50,000 images that were taken from 1963 to 1980. These photographic images were collected by the KH-7 Surveillance System and the KH-9 Mapping System. The images have variable scales and the image quality can be variable. Cloud cover is common. The film and print products are produced from a duplicate negative source. The specific image was acquired from the KH-9 Mapping System and it has a nominal resolution that ranges between 20 and 30 feet (6-9 meters). The film was scanned at 7 microns and its final size overpassed 1.3GB.

The declassified aerial photo was orthorectified taking into account more than 200 gcp's distributed in whole image. The gcp's were collected from an orthorectified Landsat 7 panchromatic image with 15m pixel size. A SRTM DEM has been used for the orthorectification of the image. The resampling method for warping the data was nearest neighbourhood interpolation and the new pixel size of 10 meters.

Then different fusion algorithm were used in order to merge the declassified aerial photo with the Landsat 1 MSS image. The optical result, the statistical parameters and different quality indexes such as ERGAS, Q, entropy and QNR were examined and the results are presented.

9245-14, Session 4

Attribute-based processing of lineament data: an example from Cesar-Rancheria and neighbor provinces in Colombia

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Relationships that allow inferring buried structures from surface lineaments can be a powerful tool in research and exploration of natural resources such as water, hydrocarbons, and economic ores. A linear characteristic of a superficial parameter genetically related to a structural, stratigraphic, sedimentary, geochemical or to a combination of these factors is a "lineament". The way lineaments reflect structures depends on the exposure degree of the affected rock. In areas not covered by recent deposits, lineaments directly reflect structures since lineaments are the intersection between planes of discontinuity with the surface. The relationship between lineaments and structures in regions covered by recent deposits may be more complex. Without neotectonics, covered structures can control both the pre-depositional topography and the location of fluids affecting deposits. Both the original materials and its subsequent affectation have the potential to print linear signals to the surface.

Satellite imagery and DEMs were used to identify 46000km of lineaments in 52000km2 of exposed and covered areas. Only public information was used in this project including middle and high resolution imagery with basic spatial and spectral processing, along with SRTM-derived datasets constituted the data sources for lineament interpretation. External geological data provided additional data that was transferred to already interpreted lineaments. Linear-referencing techniques were applied to the lineaments to obtain geological attributes. Information on province, age and rock type affected by lineaments was then used in grouping directional analyses.

This project presents a high density of directional data collected at different scales and from different sources, providing methodological contributions in data processing, particularly in external attribute acquisition.

In addition to improved fracture cartography and assessments of multiple controls on lineaments, two main applications in fossil energy exploration were proposed:

- The study of patterns of lineaments in regions covered by recent sediments, such as the Cesar-Rancheria (an oil-productive basin), and in the adjacent provinces allowed proposing a partitioning mechanism important in predicting buried structures. A combination of Sierra Nevada-rooted, divergent lineaments and NW subparallel lineaments provide a framework of clockwise increase away from Sierra Nevada.

- The characterization of lineaments patterns in terms of orientation, density, location and association with the geology of affected rocks, allowed supporting models of evolution and evaluating possible fluid migration paths. As age of affected rocks increase, NW lineaments shift clockwise in Perija province rose diagrams. Also, only some lineament patterns connect cretaceous carbonate rocks of Santa Marta province to jurassic basement rocks; these could be possible fracture-based routes for the migration of secondary porosity generating fluids. The intersection of those with other fracture families could be the location of “hot-spots” or places of unusual high porosity.

Pattern assignation process utilizes factors such as orientation, length, curvature and density. However, interpretation scale limits lineaments’ length range, influences orientation by generalization or detailing of stepped features, and affects density perception. These effects are evaluated comparing new directional statistics against original interpretations when scale information and pattern assignation are added to the grouping categories.

9245-15, Session 4

ASTER images classification using support vector machine and a particle swarm optimization, Eastern Desert, Egypt

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This paper introduces an improved classification algorithm for remote sensing ASTER satellite imagery using SVM and particle swarm optimization (PSO) algorithm. The proposed system starts with the identification of selected area of study. This is followed by a pre-processing phase using mapping polynomial algorithm as geometric correction. Followed by, applying threshold algorithm for image segmentation. Then features are extracted using object based algorithm. Followed by, image classification using SVM and particle swarm optimization (PSO). The PSO is employed as a fast global optimization algorithm instead of using traditional algorithm such as Karush-Kuhn-Tucker conditions. It is implemented and evaluated on real two selected area of interest in the North-Eastern part of the Eastern Desert of Egypt (Halaib Triangle) and (Wadi Shait). The obtained results carried out that the usage of RBF kernel function has the highest classification accuracy ratio as well as Polynomial kernel function. The new method has been proposed for the first time in this paper for lithological identification based on support vector machine (SVM) algorithm is expected to discriminate the widely exposed lithological features around Wadi Atalla area in the Central Eastern Desert of Egypt with sharp contact.

9245-17, Session 5

Diffuser properties and according performance in BSDF and spectral features in remote sensing applications

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A diffuser is a core element of calibration units in earth observation instruments. Its performance influences significantly the achievable accuracy of scientific observations.

However, the performance, in particular the Bi-Directional Scattering Function BSDF and speckle induced non-uniformities in the recorded earth observation spectra, depends on several parameters, such as surface properties, instrument configuration, observational conditions and further. This paper describes experimental activities to achieve a better understanding about the interaction between diffuser properties and performance with regards to its scattering behaviour and speckle generation on earth observation instruments.

For this purpose a set of 24 diffusers with defined surface properties, i.e. mainly the roughness related parameter R_q with a value between 0.5µm and 3.2µm, have been manufactured,. These components were systematically investigated, BSDF measurements were performed in the “Absolute Radiometric Calibration Facility ARCF” at TNO Delft in the Netherlands, a unique setup for the characterisation and calibration of optical components for space applications. A further dedicated setup was used for speckle measurements and the determination of spectral features. The achieved results show systematic patterns in the relation between surface property and performance in BSDF and speckle generation. However, our experimental results deviate from existing theoretical models, which for instance predict a significant change in BSDFwith only a slight variation in surface roughness. The measurements presented in this paper suggest a far lesser dependency and therefore indicate the necessity of further development of existing theoretical models. The derived empirical model will provide an additional data base for such further developments, furthermore it will simplify the definition and design of diffuser properties for future earth observation instruments.

9245-18, Session 5

A reliable methodology for monitoring unstable slopes: the multi-platform and multi-sensor approach

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High resolution topography, by involving Digital Terrain Models (DTMs) and further accurate techniques for a proper displacement identification, is a valuable tool for a good and reliable description of unstable slopes. By comparing multi-temporal surveys, the geomorphology of a landslide may be analyzed as well as the changes over time, the volumes transportation and the boundaries evolution. Being aware that a single technique is not sufficient to perform a reliable and accurate survey, this paper discusses the use of multi-platform, multi-source and multi-scale observations (both in terms of spatial scale and time scale) for the study and monitoring of unstable slopes. The final purpose is to highlight and validate a methodology based on multiple sensors and data integration with the aim to provide a comprehensive GIS (Geographic Information System) which can successfully be

used to manage natural disasters or to improve the knowledge of a specific phenomenon in order to prevent and mitigate the hydro-geological risk. The novelty of the present research lies in the spatial integration of multiple remote sensing techniques for the monitoring of unstable slopes, such as: integration of Airborne Laser Scanner (ALS) and Terrestrial Laser Scanner (TLS) to provide a comprehensive and accurate surface description (DTM) at a fixed epoch (spatial continuity); continuous monitoring by means of spatial integration of Automated Total Station (ATS) and GNSS (Global Navigation Satellite System) to provide accurate surface displacement identification (time continuity). Each one of the mentioned techniques is able to give a partial description of the phenomenon while the integration and the fusion of all data provide a powerful GIS allowing analysis both in time and space domain.

Great attention has been paid to the redundancy of the system in order to provide the validation of the methodology. Moreover, the critical issues of the system, capable to undermine the final GIS, have been deeply investigated. The reliability of monitoring systems, indeed, strictly depends on their infrastructure's stability which is often taken for granted; the novelty lies in the demonstration of the efficiency obtained by a proper implementation and a rigorous approach. Attention has been also paid to the coordinate system issue, which is extremely important when different datasets need to be integrated in a common reference framework for mapping purposes. Discussion makes reference to the methods adopted and to the results obtained by monitoring an active landslide and a rockslide both located in the northern Apennines of Italy from 2007 to 2011 by using ATS, GNSS, ALS and TLS in continuous and periodic mode. Being aware that TLS data processing is a tricky phase especially when long distances are involved, the paper also describes the strategy used for the point cloud alignment and for the comparison of multi-temporal DTMs. The aim is to provide a sort of guidelines about a suitable way for planning and properly performing surveys by means of multi-sensor systems. This effort is addressed to prevent for inconveniences that might influence the accuracy and the precision of final results as well the GIS and integrated analyses.

9245-19, Session 5

A fluorescence Lidar combining spectral, lifetime and imaging capabilities for the remote sensing of cultural heritage assets

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Fluorescence lidar imaging can be profitably used for the diagnostics and documentation of the monumental cultural heritage: the technique, in fact, offers several advantages since it can carry out fluorescence measurements on the monumental surface from distances as far as hundred of metres without the need for scaffolds or lifts. In addition, it provides an overall assessment of the whole investigated surface, so that it can be used to identify those specific areas in which further analytical measurements and/or sampling are needed. The main applications of the fluorescence lidar technique to the investigation of the cultural heritage concern the detection and classification of biodeteriogens, the characterisation of lithotypes, the detection of protective coatings and also the characterisation of pigments.

The fluorescence lidar relies on the use of a low-fluence pulsed laser, typically in the UV, to remotely excite fluorescence. A telescope is used to collect the signal emitted from the examined surface and a suitable dispersion, detection and acquisition system (typically an optical multi-channel analyser) is used to analyse this signal. To obtain a hyperspectral fluorescence image, a computer-controlled scanning system is used to scan the surface under investigation: in this way a fluorescence spectrum is registered for each pixel of the image and suitable data processing methods, e.g. Principal Component Analysis, can be used to produce false-colour coded thematic maps of the investigated area.

This paper addresses the latest technological advancements and results concerning both instrumental features and applications to the diagnostics and documentation of the cultural heritage. In particular, it focuses on the impact on applications of the instrument's technical upgrade in terms of scan speed, enhanced spatial resolution and field of view of the instrument, which permitted to extend the field of application of the lidar technique to wall paintings and to the classification of microbial communities. In addition, it outlines the potential of a new concept of fluorescence lidar imaging system based on the integration of hyperspectral and fluorescence lifetime spectroscopy, which enhances the capabilities of the technique for the characterization of the materials to be investigated in cultural heritage assets. The new prototype is able to acquire full 4D datasets over a remote surface: for each pixel of the image, a 3D datum featuring fluorescence intensity versus wavelength and time is recorded. Fluorescence data are acquired with a spectral resolution of 0.5 nm and a temporal resolution of 1 ns. The feasibility of measuring fluorescence lifetime features of a target can offer new insights in the investigation of complex processes such as energy-transfer between different molecules and multi-temporal decay processes.

9245-20, Session 5

Preliminary results from one of the most recent SAR airborne campaigns by MetaSensing

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MetaSensing is a Dutch company producing and operating Synthetic Aperture Radar (SAR) sensors at high resolution and different frequency bands, including P-,L-, C-, X- and Ku. By operating its most recent SAR sensors in the framework of different projects MetaSensing showed how diverse SAR imagery techniques can be applied to different areas of remote sensing, offering a potential tool for monitoring and mapping purposes. The present paper gives an overview about the last achievements of MetaSensing during recent airborne measurement campaigns, focusing the attention on preliminary results.

A fully-polarimetric L-band radar system with one meter resolution has been successfully used in March 2014 within the framework of the future SAOCOM mission, which is currently under investigation by the European Space Agency (ESA). At these low frequencies penetration capabilities for several meters is possible on dry snow. More than 40 fully polarimetric images have been acquired by MetaSensing over a glacier of the Otzal Alps, in Austria. A deeper understanding is possible with radar signals of a complex environmental system such a glacier. Some examples of the obtained results are shown on the present paper. Multiple baselines were obtained by flying the sensor over the glacier, which has been observed from two opposite view angles. The acquired SAR images will be processed to obtain Tomographic 3D images of the glacier. By means of these, an assessment of the internal structure of the glacier can be achieved.

High resolution interferometric airborne acquisitions at X- and Ku-band are repeated by MetaSensing along the delta (Rehine–Meuse–Scheldt) region of The Netherlands during different periods of the year. By exploiting multi-temporal SAR interferometric images it is possible to monitor the status of the growing vegetation in between the rivers and the relative anti-flooding barriers built along the river itself. The height and

type of such vegetation play a fundamental rule in the flooding mechanism, and local authorities need for their constant and reliable monitoring. In the paper some examples of achieved results will be presented, showing once again how radar technology is a fundamental tool in the managing process of natural resources, with particular attention in the prevention of flooding disasters.

9245-21, Session 6

Robust discrimination of permanent scatterers using Cameron Decomposition

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One of the main difficulties encountered in DInSAR applications is temporal and geometric decorrelation over time. Single pixels, called Permanent Scatterers, overcome this difficulty since they are coherent over time and wide look-angle variations [1]. Permanent Scatterers identification using interferographic techniques is unfeasible since they require the use of many acquisitions.

Samsonov and Tiampo have presented a technique that selects Permanent Scatterers by analyzing their Polarization Phase Difference (PPD) [2]. For each pixel PPD is calculated as ?? = ?hh – ?vv, where ?hh and ?vv are the phases of the polarized electromagnetic waves measured in the HH and VV channels respectively. The extreme values of PPD are equal to either zero or ±ϖ and correspond to deterministic single and double bounce scatterers [8]. For reliable scatterer selection the normalized PPD is expressed using the coefficient ?=?|??|/(kϖ) and k is the number of the SAR images employed. This coefficient ranges from zero to one where ?=0 corresponds to pixels with strictly single bounce scattering and ?=1 to strictly double bounce scattering mechanism. Furthermore, to exclude single bounce pixels corresponding to reflections from water surfaces a threshold is set on pixel amplitude.

The PPD approach would work just fine looking for single bounce scatterers because they are invariant to any initial arbitrary rotation between the scatterer and the LOS of the radar. For double bounce scatterers a problem occurs if the scatterer presents an initial orientation angle ?. If ?=45o then |?| would be set to 0. The PPD algorithm then would mistakenly consider it as a single bounce scatterer and may disregard it depending on its amplitude. Furthermore a double bounce scatterer may present such an arbitrary initial orientation angle that would make the |?| coefficient to lay between 0 and 1, and that is a highly undesirable result.

We propose to replace the PPD technique with Cameron's CTD [3] because it is more accurate in finding the single and double bounce scatterers as it eliminates the initial orientation angle ? of the scatterer. Thus, our approach is not restricted to only those pixels that present initial phase difference ??≈0 or ±ϖ. Additionally, Cameron's CTD is capable of recognizing more scattering mechanisms which means that more pixels, depending on their amplitude and stability over time, can be classified as Permanent Scatterers.

A sample scene of fully polarimetric SAR imaging the San Francisco bay was used for experimentation. This scene was obtained from the satellite RADARSAT-2 which can be found in the MDA's Geospatial Services official website. Our results demonstrate the superiority of the Cameron's CTD approach compared to PPD approach for the selection of pixels classified as Permanent Scatterers.

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9245-22, Session 6

Use of advanced SAR monitoring techniques for the assessment of the behaviour of old embankment dams

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The work discusses the use of the Ground-Based Synthetic Aperture Radar (GBSAR) interferometry technique for the monitoring of dams. The GB-SAR system consists of a stepped-frequency radar working in the Ku band that is able to give non-destructive microwave data of the observed scenes. It can be installed at distances between a few metres up to a maximum of 4 km, depending on the monitoring conditions. The GB-SAR sensor can provide 1D, 2D and 3D datasets of the observed scene, according to the acquisition mode.

In a static configuration the radar is able to acquire a line of data every 50ms, providing successive 1D profiles of the observed scene with a range resolution of about 0.50 m. The interferometric (stereo) processing of these 1D profiles result in displacement profiles with a sub-millimetre accuracy, updated every 50 ms. The applications of these kind of accurate displacement profiles are manifold, ranging from the static and dynamic testing of dams. Due to the 50 ms sampling time, accurate measurement of vibrations frequencies up to about 10 Hz can be provided by GB-SAR interferometry.

If the radar is sled along a 2m-long rail installed in front of the monitored scene, the GB-SAR interferometry technique provides 2D displacement maps of the observed scene. Each object in the scene is mapped into a GB-SAR image in terms of range and azimuth distances, where the azimuth direction is set by the orientation of the rail. These 2D maps have the same sub-millimeter accuracy of the 1D displacement profiles but can be updated only every 3 minutes. The main application of the 2D GB-SAR interferometry is the mapping of deformations of extended objects

This work discusses the use of GBSAR interferometry technique to observe and control the behavior of earthfill or rockfill embankments for dam impoundments. This non-invasive technique provides displacements patterns measured with a sub-millimeter accuracy. Besides the displacement measurement the technique is able to provide also the map of measurement accuracy depending on the coherence properties of the monitored scene. The need of reliable monitoring of old embankment dams is rapidly increasing since a large number of these structures are still equipped with old monitoring devices, usually installed some decades ago, which are generally capable to provide only localized information on specific areas of the embankment. In particular, a specific case study regarding an earthfill dam embankment in Southern Italy, which is being monitored by means of ground-based radar interferometry, SAR interferometry, along with updated monitoring devices installed throughout the dam structure is presented.

9245-23, Session 6

A methodology for luminance map retrieval using airborne hyperspectral and photogrammetric data

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Nocturnal light pollution represents a side effect of industrial civilization. Also known as photo-pollution or luminous pollution, this term usually accounts for the excessive, misdirected or undesired artificial light that may be observed over an area of interest. Its sources include buildings exterior and interior lighting, advertising, commercial properties, offices, illuminated sporting venues and, obviously, streetlights. In the last years, debates about energy efficient use as well as energy conservation stressed the importance of monitoring artificial lightening at local, regional and global scale. The former position advocates the need to use energy more efficiently, that is, using less energy for the same level of service. The latter one exhorts to address the light pollution issue by changing the habits of society, using lighting more efficiently, with less waste and less creation of unwanted or unneeded illumination. Being the final goal to be pursued the reduction of either the costs involved in the private or public area illumination or the impact on the environment, having at disposal a reliable tool to describe quantitatively the amount of artificial light radiation characterizing the earth surface becomes crucial. On the one hand, it makes it possible to detect light wastes or even outlawed light hotspots. On the other hand, it provides a quantitative descriptor to assess the effectiveness of policies and actions taken to deal with previously detected issues.

The spectral sensitivity of human visual perception of brightness is described by the photopic luminosity function defined by the Commission Internationale de l'Éclairage (CIE). In essence, the photopic curve specifies the different sensitivity of human eye to incoming light radiation at different wavelengths within the blue-to-red spectrum. It follows that a light meter must measure the amount of visible light in a given areas mimicking the human eye response. From this point of view, hyperspectral VIS-NIR sensors are versatile devices able to combine the advantages of a synoptic view achieved from airborne or satellite platforms, and a fine-sampled description of the imaged scene spectrum. These sensors are often devised for diurnal acquisitions, so that radiometric high-quality of data is achieved through high values of incoming radiance (high Signal-to-Noise Ratio or SNR). Concerning nocturnal airborne hyperspectral data, legal restrictions on the minimum flying altitude and physical constraints of platform speed often compel to deal with low values of incoming radiance. Yet, they are still suitable for light pollution measurements.

In this paper, a methodology developed at the Institut Cartogràfic i Geològic de Catalunya (ICGC) to quantify upwelling light flux using hyperspectral CASI-550 data is put forward. The study is carried out in the frame of a demonstrative study requested by the municipality of Sant Cugat, in the vicinity of Barcelona (Spain), aiming to envisage a new approach to asses lighting policies and actions. CASI night data were acquired over the urban area of Sant Cugat in January 2014. In order to avoid moon light contributions, the acquisition process was carried out during the first days of new moon phase.

First, data will be radiometrically calibrated to obtain hyperspectral radiance from original DN values. A comprehensive description of the spectral configuration of CASI as well as of the flight geometry will be also provided. Then, the atmospheric information of NCEP [4] profiles corresponding to the flown area at the capture time will be used to calculate the Column Water Vapor (CWV). This parameter will be then passed as input to ModTRAN5.0 atmosphere simulator in order to estimate the atmospheric transmissivity ? at pixel level. It is worth stressing that ? is a function of band spectral properties (central wavelength, bandwidth) and acquisition geometry (platform height, observation angle), and is key for the retrieval of hyperspectral radiance at the ground. Spectral components are then integrated according to a photopic spectral curve for the estimation of luminance information at pixel level (candela/m2). The higher SNR of the spectral-integrated information will make it possible to filter the noise patterns generated by the CCD reading process. Afterwards, the luminance map obtained by mosaicking the different flight tracks will be analyzed. Conclusions about the usefulness of the retrieved luminance information for urban energetic management will be finally drawn.

9245-24, Session 6

Airborne hyperspectral imaging in the visible-to-mid wave infrared spectral range by fusing three spectral sensors

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Airborne hyperspectral imaging is widely used for remote sensing of environment. The choice of spectral region usually depends on the availability and cost of the sensor. Visible-to-near infrared (400-1100 nm) spectral range corresponds to spectral sensitivity of relatively cheap Si detectors therefore it is the most commonly used. Implementation of shortwave infrared (1100-3000 nm) requires more expensive solutions, but can provide valuable information about the composition of the substance. Mid-wave infrared (3000-8000 nm) is rarely used for civilian applications, but it provides information on the thermal emission of materials. Fusion of different sensors allows spectral analysis of wider spectral range combining and improving already existing algorithms for analysis of chemical content and classification.

Here we introduce our Airborne Surveillance and Environmental Monitoring System (ARSENAL) that was developed by fusing six sensors operable in the spectral ranges: 280-375nm (ultraviolet, 1 spectral channel), 356-1050nm (visible-to-near infrared, up to 288 programmable spectral channels), 950-2450nm (short wave infrared, 100 spectral channels), 3000-5000nm (mid wave infrared, 64 spectral channels), 3700-4800nm (mid wave infrared , 1 spectral band with interchangeable filters), high resolutions RGB imaging sensors and a LIDAR sensor (1065nm). The ARSENAL is capable of acquiring 454 spectral bands simultaneously, and it is installed in a twin engine aircraft BN-2T-4S Defender that can provide the collection of data at low speeds and has a maximum endurance of around eight hours.

The first test flight of ARSENAL was carried out over the small town of Cesis in Latvia in early October 2013. The study area included both a variety of industrial sites, agricultural land and forests. Principal component analysis and extraction of significant spectral channels were used for data processing. Classification of land use and land cover (LULC) objects was performed based on acquired high dimensionality data. The results of data fusion of the three of ARSENAL's hyperspectral sensors in the visible-to-mid wave infrared spectral range (365-5000nm, 452 spectral channels) and data analysis will be presented. Additional airborne measurements are planned for this spring and summer, and the results will also be included.

9245-25, Session 7

Derivation of Tasseled Cap Coefficients for RapidEye data

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The RapidEye constellation with its daily revisit time is a valuable tool in studying, monitoring and managing forests and agricultural fields. Information obtained with RapidEye data, like in all remote sensing systems, needs to be translated into structural and biophysical properties of the vegetation or other surface features. The Tasseled Cap Features (TCFs) derived from Tasseled Cap Transformation (TCT) of the satellite spectral information provide a decorrelated, three-dimensional view of the inherent spectral variability of forest and agricultural scenes. In addition, the TCFs can be directly associated with biophysical characteristics of land surface features. The Tasseled Cap Coefficients (TCCs) are fixed rotation parameters, applicable to any data from the same sensor and therefore, provide a consistent interpretation context for image analysis. Since currently there are no TCCs available for the RapidEye sensor, the goal of the research reported here was to derive TCCs from RapidEye images.

To derive the TCCs the Gram-Schmidt orthonormalization (GSO) technique was used. Nearly thousand samples were extracted from several RapidEye images in East Germany. Different types of ground features (green and senescence vegetation and bare soil) associated with agricultural and forested areas were sampled. Potential TCFs were chosen using PCA and visual analyses. Based on the observed spectral variations and on ground truth data, homogeneous image samples (land cover classes) were used to construct vectors in the principal directions of the spectral variation of the predetermined surface classes. Vectors were orthonormalized by the GSO procedure to generate the corresponding TCCs.

The first TCF, Brightness, represented a weighted sum all five bands, i.e. it is sensitive to changes in total reflectance, and was oriented in the principal direction of soil brightness. The second TCF, Greenness, produced a contrast between the visible bands (including the Red-Edge band), and the near infrared band, representing the typical reflectance characteristics of vital vegetation, with relatively higher reflectance at the NIR range. The third TCF, Yellowness, showed a contrast between the blue + green band, and the red + Red-Edge + NIR. It is assumed that Yellowness is responsive to the carotenoid content and degree of chlorophyll degradation typical from senescent agricultural crops.

Based on the observation of the distribution of major feature classes within the TCF space, it offers great potential for image analysis, for example, to enhance image classification. Further studies are needed to corroborate and make the results extensive to other conditions.

9245-26, Session 7

Monitoring deforestation trend and future outlooks of the aboveground forest carbon stocks in Central Sumatra using ALOS-PALSAR mosaic data

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Accurate time-series maps are required to monitor the forest pattern, biomass condition, deforestation, underlying causes, and outline the future patterns. Evidences show that the synthetic aperture radar (SAR) data of ALOS can provide a solution for forest monitoring in tropical region because of unaffected by the haze and clouds, forest structure accountability, and temporal availability. Examining underlying causes and envisioning future circumstances of deforestation require spatial model; because it examines the forest change process, provides important abstract information about the future, and enables testing the implications of different forest policies. In this research, we present methods for monitoring tropical forest patterns and process, examine implication of the forest policies in the future forest patterns including forest carbon stocks utilizing ALOS-PALSAR data. Riau Province of central Sumatra is selected for the study as it has received worldwide attention due to forest–related carbon emissions. A spatial model is developed using the time series land cover maps which were prepared with 25 meters slope corrected PALSAR mosaic data for 2007, 2008, 2009, and 2010. This model provides the past deforestation trend and the future forest patterns guided by the three forest policy scenarios. An aboveground forest carbon stocks (AFCS) model was also calibrated with field measurement data and L-band backscatters from 10 meters slope corrected PALSAR mosaic data of 2009 and 2010. A total of 87 plots of field measured AFCS data ranging 1 - 340 t/ha were used. This AFCS model provides the AFCS map with root mean square error of ±45 t/ha. We found that a large part of the forest was deforested in the past. The future spatial patterns of the deforestation between the policy scenarios are apparent. If the historical trend continues, the forest cover will be consistently disappeared leaving very few small forest patches by 2030. However, one of the governance scenarios has produced a balanced forest spatial pattern in the province as compared to the other scenarios. The spatial patterns produced by the scenarios were overlaid with AFCS map to estimate the spatial patterns of carbon stocks and quantify the potential emission from deforestation by 2030. Our preliminary estimate shows that if the forest process follows the past trend, about 550 million tons of AFCS will likely be in the atmosphere by 2030. However, one of the forest scenarios projected that the half of the AFCS can be still saved from the emission.

9245-27, Session 7

Delimitation and Analysis of Environmental Protection Areas in the Paraíba do Sul River Basin in Brazil

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This work establishes a methodology to evaluate the Environmental Protection Areas (EPA) in the Paraíba do Sul River basin, located in the southeastern region of Brazil. EPA are Sustainable Use Units, that harmonize nature conservation with sustainable use of natural resources. Activities that involve the collection and use of natural resources are permitted provided that such practices ensure the sustainability of renewable environmental resources and ecological processes. The study of EPA in this work is linked to the uptaking of water by the cities of the Paraíba do Sul basin. We want to know the environmental conditions of water within the EPA to determine which interventions are necessary in order to ensure the quality of water that is suitable for the needs in a city. To develop this work six source points have been defined. Each point refers to the water collection for consumption in a city. The drainage networks of the study area were extracted by using the system for distributed hydrological modeling TerraHidro, which was developed at the National Institute for Space Research (INPE), Brazil. Data from the ASTER GDEM surface model with 30 meter resolution and SRTM data with 90 meter resolution were used by TerraHidro for extraction of drainage networks. Following, contribution areas were bounded from defined drainage networks. For each source point, the portion of the earth's surface that influences the quality of water that reaches this point defines the boundaries of an EPA. The river basin has been adopted as the unit of water resources planning and this unit will be fundamental in all studies related to the environment. Remote sensing allows extending the study of hydrology at the local scale for assessment of EPA in spatial scale. To analyze the quality of water is necessary to know which elements are within the EPA and the amount and the location of each element. Landsat and RapidEye images, with 30 and 5 meter resolution were used, respectively, to define these elements. Situations as diffuse pollution caused by application of pesticides and sanitation problems in urban areas in terms of risk of contamination in the catchment areas due to domestic sewage were considered. Verification of areas with steep slopes and exposed soil, which can cause leaching and siltation was also considered in the images classification. Finally, for each EPA, an analysis was performed considering the percentage of each element, its position and relations among neighboring elements, to know which one could significantly influence the quality of collected water. This work shows a methodology for EPA defined by water collection points in cities. This study does not consider field work, which should be performed by the technicians of the Chico Mendes Institute for Biodiversity Conservation (ICMBIO), an agency of the Ministry of Environment of Brazil that is responsible for all studies involving EPA in the Paraíba do Sul river basin.

9245-28, Session 7

Land cover disturbance due to tourism in Jeseniky mountain region: a remote sensing and GIS based approach

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The Jeseníky Mountains tourism in Czech Republic is unique for its floristic richness, which is caused mainly by the altitude division and polymorphism of the landscape; climate and oil structure are other important factors. This study assesses the impacts of tourism on the land cover in the Jeseniky mountain region by comparing multi-temporal Landsat imagery (1991, 2001 and 2013) to describe the rate and extent of land-cover change throughout the Jeseniky mountain region. This was achieved through spectral classification of different land cover and by assessing the change in forest; settlements; pasture and agriculture in relation to increasing distances (5, 10 and 15 km) from three tourism site. The results indicate that the area was deforested (11.13%) from 1991 to 2001 than experienced forest regrowth (6.71%) from 2001 to 2013. In first decay pasture and agriculture areas was increase and then in next decay it was decrease. The influence of tourism facilities on land cover is also variable. Around each of the tourism site sampled there was a general trend of forest removal decreasing as the distance from each village increased, which indicates tourism does have a negative impact on forests. However, there was an opposite trend from 2001 to 2013 that indicate conservation area. The interplay among global (tourism, climate), regional (national policies, large-river management), and local (construction and agriculture, energy and water sources to support the tourism industry) factors drives a distinctive but complex pattern of land-use and land-cover disturbance.

9245-38, Session 7

Retrieval and verification of fire radiative power using the Korean Geostationary Meteorological Satellite

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Global climate warming induced by greenhouse gases is increasing wildfire frequencies and scale. Thus, many researchers have been interested in studies of observing wildfire. Global wildfires have burned 9,200Mt ± 50% vegetation every year. California wildfire in 2006 were released 8.7 million tons of carbon dioxide during the week. It equals to annual usage of fossil fuel in California. Like this, It can bring about a terrible atmosphere pollutions even through it occur only one time. Therefore, we should be concerned about contribution rate of GHGs caused by wildfire in atmosphere. Greenhouse gases by wildfires were depend on the combustion experiment and field observation in the past. However, it is limited. because wildfire occurs irregularly in a wide areas. Thus, most efficient way for detection of them is satellite-based fire detection because wildfires occur in any space and time. The American MODIS (Moderate Resolution Imaging Spectroradiometer) is now providing the satellite products for active wildfires. Most studies on wildfire have been using the MODIS that is polar orbiting satellite. It cannot constantly produce fire information because of observing once or twice a day. Therefore the geostationary satellite is more reasonable than MODIS. Recently, the American GOES-R (Geostationary Operational Environmental Satellite - R Series) the European SEVIRI (Spinning Enhanced Visible and Infrared Imager) are studying on wildfire product by MODIS algorithm. However,

these observe the America, Europe and Africa. The COMS and MTSAT(Multi-functional Transport Satellite-1 Replacement) that are able to observe in East Asia and Oceania, do not have technology to create wildfire products until now.

Therefore, we are aim to create both existing fire products (fire mask, FRP (Fire Radiative Power), confidence level etc.) and the information of GHGs using the COMS (Communication, Ocean and Meteorological Satellite). The FRP to be linked the GHGs and wildfire products of the satellite, is more important than the other fire products. In this paper, we calculated COMS FRP in East Asia in April 2011 and 2012, using the single waveband method that needs only middle infrared channel because of limit of its channel. The FRP was verified by matching the space and time with the MODIS after selecting conclusive wildfires. As verification result, we considered our COMS FRP to be available. The future, we are scheduled to retrieve biomass combustion and the GHGs using our FRP and vegetation information. The FRP and rate of biomass combustion are expected to be utilized as an important parameter for the studies of combustion engineering, aerosols, and global/regional carbon cycle. Our products can be also utilized as the baseline for retrieval of certified emission reductions.

9245-46, Session PS

Mesoscale observational analysis of a strong squall line in Its genesis and development over the Song-Nen plain of NE China

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A mesoscale observational analysis is performed of an event of rainstorm and intense convective weather as a robust happening during a 100-yr return period on August 10, 2006 in the Song-Nen Plain of NE China by use of minute-level automatic-station data, high-resolution satellite cloud maps, new-generation Doppler soundings and conventional observations. Results show that this event of rainstorm and robust convective weather is bound up with the genesis and development of a squall line, which causes great change in station meteorological elements on its way. At the Tailai station, for instance, precipitation is the strongest, reaching 90.8 mm/h, where temperature drops by 21.50C, pressure rises by 4.7 hPa and winds peak between 13.3 to 22.6 m/s during the squall passage. The squall line is displayed as an elliptical MCC on satellite cloud maps and by analyzing radar images for echo top height, intensity, velocity and shape the genesis and development of the squall line are derived. It is discovered that multiple meso – convective cells evolve into circular meso-convective complexes prior to the MCC production. At the mature MCC stage these complexes evolve into a squall line, which shows a process for forming a meso-convective system previously to the genesis of a squall line. At first there occur a range of meso-convective cells that are steadily appearing and disappearing owing to unevenly striking solar radiation around the stratiform clouds. Through the ~50-min breeding time a comma-shaped meso-convective storm is generated, followed by developing towards the southwest part of the storm with bow-like echo zones shown, followed by gradual appearance of multiple super cells, viz., multi-cell storm in the southwestern end of the echoes. These intense convective storm comprise linear strong convective echo bands, ~315 km in total length and 50 km wide, persisting for ~7 hrs. When the squall line passes, there emerge, in order, a front low, a thunderstorm high and a wake low that differ in intensity, with the high zone exhibited as close-together contours on surface maps, and as positive allobaric centers and cold air piles on allobaric and allo-temperature diagrams, respectively. It is expected that through the present meso analysis of the rainstorm we are allowed to make nowcasting of such events.

9245-47, Session PS

Remote sensing technology and geographic information system (GIS) in order to identify the relationship between the natural setting (environment) and the spread of disease

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The main goal of this study is the use of Remote Sensing technology and Geographic information system (GIS) in order to identify the relationship between the natural setting (environment) and the spread of disease (MALARIA)) epidemic in the Southwestern part of Kingdom of Saudi Arabia (Jazan Region). A working groups was established from several government sectores (ministries) related to the work of land survey in order to plot features to the maps. Remote Sensing technology (space digital image processing and analysis) gave general view about; Normalized Difference Vegetation Index (NDVI), permanent swamps and many different maps. All the available statistical data, maps, space images (American Landsat satellite images and French Spot satellite images) results and the result of the land survey loaded to Special Geo-database in order to produce analysis maps. The weather maps, environmental maps, mosquitoes and population density maps, infected human and animals (in light of geographic locations) with the spread of disease , but there is no an ideal (Model) relationship. This study included the distribution of the appropriate disease carrier (mosquitoes) and presented in light of geographic locations and population density during the different seasons.

This study ends by scientific recommendations for the importance of the use of modern technologies in designing of the early alert system for epidemic diseases by cooperation from governmental sectors.

9245-48, Session PS

Desertification modelling and assessment using remote sensing and GIS

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The economic and social conditions that have occurred in the Kingdom of Saudi Arabia in the beginning of the twentieth century led unintentionally and indirectly to increase the desertification process, which has become a threat to the environment.

This study aims to identify the indictor of desertification in part of the kingdom. Through the monitor and identify the criteria of desertification processes dominated in the kingdom and then build models of the processes affecting desertification.

Integrated approach has been used to combines different methods adopted in the assessment processes of desertification of various kinds (climate change and drought, land degradation and human activities), and review of previous studies in order to reach a better concept of some indicators of desertification in the kingdom.

Both Al-Ahsa oasis and Al-Qassim region are the most

vulnerable regions of the Kingdom of desertification and both are affected by variety of factors that cause climate significantly in the growth of desertified land.

The Geographic Information System (GIS) software used for data collection, save data and various maps in order to create a Geographic Information database contains the basic information (For study areas) to assess the different environmental processes (Desertification) in the integrated system and then design a models for desertification indicators

9245-49, Session PS

Producing large scale GIS ready base map and ground truth from GE images

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Mapping of urban area includes different types of features (e.g. roads and buildings). Large scale maps could be achieved from VHR satellite images such as QuickBird, Ikonos, Geoeye-1 images. Archived images and field verifications are costly for researchers especially in developing countries. Google Earth (GE) provides free access to high resolution satellite imagery. Google Earth can be collected with different resolution according to eye altitude will be taken into consideration. The main objective of this research is exploring the accuracy of producing maps with large scale from free Google Earth imagery at suitable eye altitude to be used as reference data or Ground truth for the purpose of comparison study. Two study areas has been selected for this study first one Marsa Alam city, located in Red sea Governorate, Egypt. Second one was Located in South Cairo, Giza, Governorate. The methodology involved Image collection and image rectification using suitable rectification methods with different number and distributions of GCPs and CPs collected from GE and field. Database and GIS design and development were then executed based on the requirement of large scale map. Geographic information systems (GIS) layers were created by on-screen Vectorization. In this research the results show that, the planimetric accuracy of the maps from Google Earth range from 1:5,000 to 1:10,000 according to eye altitude of the collected GE images and can be used as reference data or Ground truth for classification purposes.

9245-51, Session PS

Exploration of the OBIA methods available in SPRING non-commercial software to UAV data processing

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The increasing developments in Unmanned Aerial Vehicles (UAVs) platforms and associated sensing technologies, offer a broad range of solutions for different applications related to the acquisition of information about objects or phenomenon at the Earth. The huge amount of data, provided by UAVs, represents a new challenge regarding developments of image processing techniques. Object-based image classification (OBIA) is highly suitable for very high resolution imagery, where pixel-based classification is less successful due to the high spatial variability within objects of interest.

An OBIA approach using SPRING non-commercial software was implemented in this work. In its most basic form, OBIA consists of classification of image objects, but more commonly a recursive approach is implemented using image segmentation, classification of image objects, merging of objects, re-segmentation and re-classification using the incorporation of spectral, spatial, and contextual features for extraction of meaningful image objects [1]. The segmentation algorithm available in SPRING uses region growing segmentation method. It has two parameters, “similarity” and “area”, to guide the segmentation procedure. “Similarity” is a threshold value that determines if two neighbouring pixels (objects) are grouped, while the “area” threshold is used to filter out the objects smaller than this value. A good segmentation is crucial for a highly accurate classification.

The UAV system used in this work to collect the images (transverse overlap 60%; longitudinal overlap 80%; average altitude 160m) was a Swinglet from Sensefly. The system has the following main characteristics: weight less than 0.5 kg; an U-Blox GPS chip; an altitude sensor; a digital camera (Canon IXUS 1201S) with 12 megapixel of the visible region, a radio transmitter and a circuit board with autopilot. The image ortho-rectification (RMS 0.0076 m in planimetric and 0.742 in altimetry) and ortho-mosaic computation was already done and was performed using Agisoft PhotoScan Pro ® software. Two ortho-mosaics, with 0.04 m of pixel size, from 20 and 28 of January of 2012 of Coimbra (Portugal) region with na apx. 500x400m area was processed using the original 41 images. For each ortho-mosiac different “similarity” and “area” parameters combination were computed in the segmentation stage. Due to the very high spatial resolution of the images, the segmentation stage is a very time consuming stage. After, an unsupervised classification was performed using the Isoseg algorithm. Depending of the “similarity” and “area” parameters defined in the segmentation stage, different classes were assigned. A visual validation was performed in order to aggregate similar classes. A supervised classification was also computing, using the Battacharya distance algorithm. Once again, the classes assignment depends on the parameters defined in the segmentation stage. Generally, the results obtained in the supervised classification present more reliable results, with an overall accuracy higher than 90% and a Kappa higher than 0.9. Finally, the spatial data are converted to vector format and analysed in a GIS environment, in order to produce land use/cover classes. The results were in agreement with the information available in an orthophoto of the same area that was used to validate this process.

[1] Blaschke, T. Object based image analysis for remote sensing. ISPRS J. Photogramm. 2010, 65, 2-16.

9245-52, Session PS

Geologic exploration using new high-spatial resolution Mapping Satellite-1 remote sensing data in arid region, China

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Geologists have used remote sensing data for geologic exploration, the remote sensing technique is normally used in acquiring Earth’s surface geological data for instance structural features, lithologies etc. In this paper, The new Chinese Satellite “Mapping Satellite-1” system, launched on December 24. 2010, was used for geologic exploration because of its high spatial resolution and stereo capability, “Mapping Satellite-1” is designed with four bands in the VNIR spectral range with a 10 m spatial resolution, and 60km swath width. The “Mapping Satellite-1” remote sensing data can be used for lithologic mapping and for detection and delineation of faults, and for detection of hydrothermal alteration rock. The geologic study area is located in arid region, northwest of China, vegetation overlap is thin in this area. This region is covered by volcanic rock. In this paper, “Mapping Satellite-1” data was used to study structural features, lithologies, Ferric iron minerals of the study area. Results from “Mapping Satellite-1” data analyses show clear correlation between “Mapping Satellite-1” image and geological map of study area, and results from “Mapping Satellite-1” data analyses were proved by fieldwork.

9245-53, Session PS

Analysis of urbanization and climate change impacts on the urban thermal environment based on MODIS satellite data

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Urbanization, the conversion of other types of land to uses associated with growth of populations and economy has a great impact on both micro-climate as well as macro-climate. Cities are exposed more and more to climate change from greenhouse gas induced radiative forcing, and localized effects from urbanization such as the urban heat island. Urban land covers as the biophysical state of the earth's surface and immediate subsurface, are sources and sinks for most of the material and energy movements and

interactions between the geosphere and biosphere.Climate change is considered to be the biggest environmental threat in the future in the South- Eastern part of Europe. The aim of this paper is to investigate the influences of urban growth on urban thermal environment as well as the relationships of thermal characteristics to other biophysical parameters in Bucharest metropolitan area of Romania based on time series MODIS Terra/Aqua and IKONOS data acquired during 2000-2014 period. Land Surface Temperature (LST) is a key variable for studying urban land surface processes and surface atmosphere interactions, being a crucial component in the study of the surface energy and water budgets. Correlation analyses were conducted to investigate the changing relationships of LST with impervious surface and vegetation coverage. Results indicate that multi-temporal fraction images were effective for quantifying the dynamics of urban morphology and for deriving a reliable measurement of environmental variables such as vegetation abundance and impervious surface coverage. Urbanization created an evolved inverse relationship between impervious and vegetation coverage, and brought about new LST patterns because of LST's correlations with both impervious and vegetation coverage. Climate change and urban growth result in a greater increase of hot nights for Bucharest city than neighboring periurban areas, increasing the thermal stress and vulnerability to heat waves of urban citizens in a warmer climate compared to their rural zones. City thermal environment risk management strategies for mitigating and adapting to climate change must propose efficient plans to reduce greenhouse gas (GHG) emissions and cool the city through changes in the built environment, land use, and transportation.

9245-54, Session PS

Evaluation of remote sensing data potential in the geological exploration of Freixeda area, Mirandela, Portugal: a preliminary study

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The value of remote sensing data to geological exploration has increased as technology has improved. The advent of multispectral and hyperspectral imaging has allowed surface mapping to be performed remotely, thereby enabling vast areas to be mapped in a short time at a fraction of the cost of traditional geologic mapping. Different scanning spectrums enabled researchers to begin cataloguing various reflection and adsorption properties of soils, rock, and vegetation. These spectra could be used to interpret actual surface lithologies from remote sensing images. Geological remote sensing has been ill-defined in the literature. Sabins (1999) wrote probably one of the most sold and cited textbooks on remote sensing [1]. During the early days of Landsat MSS and TM, geologists developed band ratio techniques and selective principal component analysis to produce iron oxide and hydroxyl images that could be related to hydrothermal alteration. The advent of ASTER sensor with six channels in the shortwave infrared and five channels in the thermal region allowed to produce qualitative surface mineral maps of clay minerals (kaolinite, illite), sulfate minerals (alunite), carbonate minerals (calcite, dolomite), iron oxides (hematite, goethite), and silica (quartz) which allowed to map alteration facies (propylitic, argillic, etc.) [2].

The study area focused in this work was the Freixeda stretch (41º25'04'' N - 7 °06'29'' W), district of Mirandela. In Freixeda, the seismic activity is constant (low magnitude). The presence of a major fault that can be considered active (Vilariça fault), which is encompassed by a tectonic accident: Bragança-Vilariça-Manteigas, with a length of 250 km, where the last 9 km corresponds to Vilariça fault should be reported. Is also important report the presence of a mineralized area - the Freixeda mine.

In this work, an ASTER image (March 2011) from the study area was obtained from USGS Earth Resources Observation and Science (EROS) Center freely. ASTER VNIR and SWIR reflectance data have been used to produce colour composite images that seek to maximize the lithological information in the area; ratio images have been used to highlight ferric iron; and relative band depth images of the SWIR bands have been used to predict the occurrence of Alunite/Pyrophyllite, Kaolinite, Illite and Prophylitic group minerals. The VNIR bands were used to define vegetation and also ferric iron. Ferric iron is defined by the ratio of band 2/band 1 (red/ green).The vegetation ratio is defined by the ratio of band 3/band 2. The SWIR data consists of 6 bands (band 4 – 9). Band 4 is located where most cover types have maximum reflectivity. Bands 5 to 9 cover an area of the SWIR where many-OH bearing minerals and carbonate minerals have absorption features. The presence of Au and Ag mineralization confirm the richness of this area. This study, although preliminary, found it of considerable interest. It is currently in progress a project to explore with more detail this approach.

[1] Sabins, F.F., 1999. Remote sensing for mineral exploration. Ore Geology Reviews 14,157–183.

[2] Freek D. van der Meer, F. et al., 2012. Multi- and hyperspectral geologic remote sensing: A review. International Journal of Applied Earth Observation and Geoinformation 14, 112–128.

9245-55, Session PS

Monitoring land use/cover changes on the Romanian Black Sea Coast

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The marine coasts, named as the natural sources, remaining untouched by human being for centuries brought up new ways of usage first by providing profile in terms of sea products and transportation, parallel to the development in social life forms and then by the increase in population and technological improvements. Remotely sensed satellite data

are critical to understanding the coastal zones' physical and social systems interaction, complementing ground based methods and providing accurate wide range, objective and comparable, at widely-varying scales, synoptically data. For some environmental agreements remote sensing may provide the only viable means of compliance verification because the phenomena are monitored occurs over large and inaccessible geographic areas. The main aim of this paper was the assessment of coastal zone land cover/use changes based on fusion technique of satellite remote sensing imagery. The evaluation of coastal zone landscapes was based upon different sub-functions which refer to landscape features such as water, soil, land-use, buildings, groundwater, and biotope types. A newly proposed sub-pixel mapping algorithm was applied to a set of multispectral and multitemporal satellite data for Danube Delta, Constantza and Black Sea coastal zone areas in Romania. A land cover classification and subsequent environmental quality analysis for change detection was done based on Landsat TM , Landsat ETM, MODIS, and IKONOS satellite images over 1990 to 2013 period of time. Spectral signatures of different terrain features have been used to separate and classify surface units of coastal zone and sub-coastal zone area. The change in the position of the coastline in Constantza area was examined in relation with the urban expansion. A complex analysis was done for Danube Delta spatio-temporal changes. A distinction was made between landfill/sedimentation processes on the one hand and dredging/erosion processes on the other. A quasi-linear model was used to model the rate of shoreline change linked to anthropogenic and coastal erosion. We considered the Romanian Black Sea coastal zone dynamics in connection with the spatio-temporal variation of physical and biogeochemical processes and their influences on the environmental state in the near-shore area. Such information was related to geomorphologic processes, coastal erosion, sedimentation transport, mapping of macrophyte fields and derived estimation primary production, mapping of types of marine and delta floor, and assessment of the water-column quality (concentration of sediment, chlorophyll, terrigenous substances). Such information was related to geomorphologic processes, coastal erosion, sedimentation transport, mapping of macrophyte fields and derived estimation primary production, mapping of types of marine and delta floor, and assessment of the water-column quality (concentration of sediment, chlorophyll, terrigenous substances).

9245-57, Session PS

Results of the application of persistent scatterers interferometry for surface displacements monitoring in the Azul open pit manganese mine, Carajás province, Amazon region, using TerraSAR-X data

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Manganese, the fourth most widely used metal in the world, it is mostly used in the steel industry, but with others uses (batteries, paint, fertilizers, etc.). Brazil has 10% of global Mn reserves, after Ukraine, South Africa and Australia. Fully owned by Vale mining company, the second world´s largest mining company, the Azul deposit is located in the easternmost border of the Brazilian Amazon with reserves of 45.4 Mt with 40.5% Mn content (proven), 8.3 Mt with 39.5% Mn content (probable), and ore production of 2.065 Mt in 2011. The deposit is related to pelitic sedimentary rocks of the Águas Claras Formation (Archean). It is formed by sandstones and siltstones, rich in carbonaceous organic matter and/or Mn oxi-hydroxides, characteristics of terrigenous/chemical and lateritic sources. Structurally, the deposit is located in the central portion of the Carajás Strike-Slip System (CSSS). The parallelism of the structural trends in the mine area and lineaments related to the CSSS suggests a close relation with regional deformation (dextral transtensional and sinistral transpressional episodes). Now spanning three simultaneous open-pit mine operations, the Azul mine presents excavations with pit walls of 4-8 m bench heights, 5m bench widths and 80 m deep. Slope instabilities can cause loss of equipment and risk to personnel, disrupting mine scheduling with an increase in production cost. Excavations are conducted on materials of low geomechanical quality (saprolitic soil/rock mass) and heavy precipitation periods. A stack with 19 TSX-1 StripMap scenes (repeat cycle of 11 days) was used for the investigation covering the dry season (March 20-October 4, 2012). The SLC images were acquired under ascending passes (look azimuth ~ 80 degrees) and nominal incidence ~ 40 degrees. In order to minimize the topography phase error in the interferometric process, a high resolution DEM (spatial resolution of 2m and vertical accuracy of 1.5 m) was generated based on a panchromatic GeoEye-1 stereo pair. Persistent Scatterer Interferometry (PSI) analysis was carried out using the IPTA module (Gamma RS software) and led to the detection of 40,193 PSs, with an average density of about 8,588 PSs/km2. On general, it was concluded that most of the area can be considered stable during the TSX-1 coverage, including pit benches (walls, floors), tailings pond, haul road ramps and mining infrastructure. High deformation rates showing motion away from the satellite and indicative of settlements were mapped over waste pile (deformation rate = 170mm/year, LOS displacements = 86.46 mm), with values that are normally expected for this mining structure. However, a small deformation rate with positive values and expressing motion toward the satellite was detected along slopes of the northern flank of pit 1 (deformation rate = 46.68 mm/year, LOS displacement = 24.11 mm). This deformation was not previously detected and the causes are under analysis. The investigation highlighted the important role that PSI technique could play in mining planning and risk assessment. A synoptic view of the stability conditions on a detailed scale (sub-centimeter) was provided over a large area, with the identification of sectors where field based monitoring techniques are necessary.

9245-58, Session PS

Algorithms for lineaments detection in processing of multispectral images

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Satellite remote sensing is a universal tool to investigate the different areas of Earth and environmental sciences. The advancement of the implementation capabilities of the optoelectronic devices which are long-term-tested in the laboratory and the field and are mounted on-board of the remote sensing platforms further improves the capability of instruments to acquire information about the Earth and its resources in global, regional and local scales. With the start of new high-spatial and spectral resolution satellite and aircraft imagery new applications for large-scale mapping and monitoring becomes possible. The integration with Geographic Information Systems (GIS) allows a synergistic processing of the multi-source spatial and spectral data. Here we present the results of a joint project DFNI I01/8 funded by the Bulgarian Science Fund focused on the algorithms of the preprocessing and the processing spectral data by using the methods of the corrections and of the visual and automatic interpretation. The objects of this study are lineaments. The lineaments are basically the line features on the earth's surface which are a

sign of the geological structures. The geological lineaments usually appear on the multispectral images like lines or edges or linear shapes which is the result of the color variations of the surface structures. The basic geometry of a line is orientation, length and curve. The detection of the geological lineaments is an important operation in the exploration for mineral deposits, in the investigation of active fault patterns, in the prospecting of water resources, in the protecting people, etc. In this study the integrated approach for the detecting of the lineaments is applied. It combines together the methods of the visual interpretation of various geological and geographical indications in the multispectral satellite images, the application of the spatial analysis in GIS and the automatic processing of the multispectral images by Canny algorithm, Directional Filter and Neural Network. Landsat multispectral images of the Eastern Rhodopes in Bulgaria for carrying out the procedure are used. Canny algorithm for extracting edges represents series of filters (Gaussian, Sobel, etc.) applied to all bands of the image using the free IDL source. Directional Filter is applied to sharpen the image in a specific preferred direction. Another method is the Neural Network algorithm for recognizing lineaments. The lineaments are effectively extracted using different methods of automatic. The results from the above mentioned methods are compared to the results derived from the visual interpretation of satellite images and from the geological map. In conclusion, the rose-diagrams of the distribution of the geological lineaments and the maps of their density are completed.

9245-59, Session PS

Prioritization criteria of objective indexes for disaster management by satellite image processing

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The outputs obtained from satellite image processing generally presents various information based on the interpretation technique, selected objects for object based processing, precision of processing, the number and time of images used for this process. This issue should be managed well during a disaster management process based on satellite images. Very high resolution (VHR) optical satellite data are potential sources to provide detailed information on damage and geological changes for a large area in a short time. In this paper, we studied tsunami triggered area, which was caused on 11 March 2011 by Tohoku earthquake, using VHR data from GeoEye-1 satellite images. A set of pre and post-earthquake images were used to perform visual change analysis through comparison of these data. These images include the data of the same area before the disaster in normal condition and after the disaster which caused changes and also some modification imposed to that area. Upon occurrence of a disaster, the images are used to estimate the extent of the damage. Then based on disaster management criteria and the needs for recovery and reconstruction, the priorities for object based classification indexes are defined. In post-disaster management, they are used for reconstruction and sustainable development activities. Finally a classified characteristic definition has been proposed which can be used as sample indexes prioritization criteria for disaster management based on satellite image processing. This prioritization criteria are based on an object based processing technique and can be further developed for other image processing methods.

9245-60, Session PS

Using SRTM, land use and time of concentration define critical distance for studying diffuse source pollution

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Studies for quantifying and controlling diffuse sources of pollution have been developed relating land use to changes in the surface water quality. Such studies range from simple correlation between variables to sophisticated mathematical models integrated in a Geographic Information System (GIS). Diffuse sources of pollution are inherently spread throughout a watershed and reach the watercourse along all its course. This aspect makes the association between pollution source and changes in water quality a complicated issue. It is generally agreed that to land closer to the river banks has the most pronounced effect on water quality. This makes it often necessary for government water agencies to define critical distances from which land use impacts more significantly on the observed water quality parameters. The definition of these distances should consider the land use and occupation as well as pollution source and hydraulic characteristics that facilitate or retard the flow, such as slope and roughness. In this article a digital elevation model (DEM) from the SRTM was used to compute the slope and images from the RapidEye satellite constellation were used to produce a land cover map with eight classes: vegetation, agro-pastoral, urban, meadow, wooded savanna, planted forest, barren land and wetlands. Other less important classes have been merged these eight classes. We implemented our approach using a region-based segmentation/classification software to produce the land cover map. We then used the local slope to calculate time of concentration using the U.S. Army Corps of Engineers equation and define six “time” buffers : 5, 10, 20, 30, 45 and 60 minutes. The proportion of each land use class within each time buffer are associated with changes in water quality through multiple regression. Five water quality parameters are analyzed: turbidity, phosphorus, nitrate, faecal coliform and dissolved oxygen considering different levels of discharge (flow duration). The flow duration curve (FDC) was used to separate our database in three subsets corresponding to Q <35, Q 35-70 and Q >70 flow durations. A total of 35 water quality stations pertaining to the Velhas river basin in Brazil were analyzed. The Velhas watershed covers an area of 27,867 square kilometers and is an important basin hosting the capital city of Minas Gerais, Belo Horizonte. Initial results are encouraging and proved superior to other models using fixed width buffers in the same watershed. Eighteen regression were performed for each water quality parameter. The following gives an overview of the coefficients of determination range: dissolved oxygen, 0.70-0.80; turbidity, 0.56-0.76; faecal coliform, 0.61-0.80; nitrate, 0.54-0.76 and phosphorous, 0.58-0.83. The general behavior of plots of the coefficients of determination show that shorter times of concentration explain better the variance and thus are more critical to water quality. Some parameters have a very different behavior at different flow duration proving consistent our approach.

9245-61, Session PS

Effects of band selection on endmember extraction for forestry applications

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In spectral unmixing theory, data reduction techniques play an important role as hyperspectral imagery contains an immense amount of data, posing many challenging problems such as data storage, computational efficiency, and the so called "curse of dimensionality". Feature extraction and feature selection are the two main approaches for dimensionality reduction. Feature extraction techniques are used for reducing the dimensionality of the hyperspectral data by applying transforms on hyperspectral data. Feature selection techniques retain the physical meaning of the data by selecting a set of bands from the input hyperspectral dataset, which mainly contain the information needed for spectral unmixing. Although feature selection techniques are well-known for their dimensionality reduction potentials they are rarely used in the unmixing process. The majority of the existing state-of-the-art dimensionality reduction methods set criteria to the spectral information, which is derived by the whole wavelength, in order to define the optimum spectral subspace. These criteria are not associated with any particular application but with the data statistics, such as correlation and entropy values. However, each application is associated with specific land cover materials, whose spectral characteristics present variations in specific wavelengths. In forestry for example, many applications focus on tree leaves, in which specific pigments such as chlorophyll, xanthophyll, etc. determine the wavelengths where tree species, diseases, etc., can be detected. For such applications, when the unmixing process is applied, the tree species, diseases, etc., are the endmembers of interest. This paper focuses on investigating the effects of band selection on the endmember extraction by exploiting the information of the vegetation absorbance spectral zones. More precisely, it is explored whether endmember extraction can be optimized when specific sets of initial bands related to leaf spectral characteristics are selected.

Experiments comprise a) application of the endmember extraction on the whole dataset, and b) application of band selection prior to the endmember extraction. The hyperspectral image used has 72 bands equally distributed in the spectral region ranging from 400 to 1050nm, and 2.5-3m spatial resolution. The image has initially been corrected radiometrically and atmospherically and then was orthorectified. It presents a forest area in Chalkidiki, Greece. Common forest species in the area are Italian oak (Quercus frainetto), Black pine (Pinus nigra), Beech (Fagus sylvatica) and Norway spruce (Pice aabies). Gradually, mixed stands have been formed as deciduous species invade the areas occupied by pines. Also, patches within the forest are covered with maquis (Quercus ilex, Quercus coccifera, Erica arborea, etc.), low herbaceous vegetation and scattered oak trees.

State of the art algorithms for signal subspace estimation, dimensionality reduction, and endmember extraction were initially applied on the whole dataset. A set of endmembers has been extracted. Then, based on vegetation spectral characteristics, sets of bands have been selected, which formed the new hyperspectral input set for the endmember extraction. A new set of endmembers has been extracted. All the alternate approaches are analysed in detail and their performance in endmember extraction is evaluated.

9245-62, Session PS

A framework for air quality monitoring based on free public data and open source tools

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In the recent years more and more widely accepted by the Space agencies (e.g. NASA, ESA) is the policy toward provision of Earth observation (EO) data and end products concerning air quality especially in large urban areas without cost to researchers and SMEs. Those EO data are complemented by increasing amount of in-situ data also provided at no cost either from national authorities or having crowdsourced origin. This accessibility together with the increased processing capabilities of the free and open source software is a prerequisite for creation of solid framework for air modeling in support of decision making at medium and small scale. Essential part of this framework is web-based GIS mapping tool responsible for dissemination of the outputs generated.

In this research an attempt is made to establish a framework based solely on openly accessible data on air quality and on set of freely available programs for processing and modeling taking into account the present status quo in Bulgaria. Among the sources of primary data for different types of gases and dust, especially in bigger urban areas, noted should be the National Institute of Meteorology and Hydrology of Bulgaria and National System for Environmental Monitoring managed by Bulgarian Executive Environmental Agency. Both authorities provide data for concentration of several gases just to mention CO, CO2, NO2, and fine suspended dust (PM10, PM2,5) on monthly (for some data on daily) basis. In the framework proposed these data will complement data from satellite-based sensors such as OMI instrument aboard EOS-Aura satellite and from TROPOMI instrument payload for future ESA Sentinel-5P mission. Integral part of the framework is the modern map for the land use which is provided from EEA by initiative GIO Land CORINE. This map is also a product from EO data distributed at European level.

First and above all, our effort is focused on provision to the wider public living in urbanized areas with one reliable source of information on the present conditions of air quality. Also this information might be used as indicator for presence of acid rains for agriculture areas close to industrial or electricity plants. Its availability at regular basis makes such information valuable source in case of manmade industrial disasters or incidents such as forest fires. Key issue in developing this framework is to ensure the delivery of reliable data products related to air quality at smaller scale that those available at the moment.

9245-63, Session PS

Bore-sight calibration of the profile laser scanner using a large size exterior calibration field

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The bore-sight calibration procedure of a profile laser scanner using a large size exterior calibration field is presented in the paper. The task is a part of Autonomous Mapping Airship (AMA) project which aims to create s surveying system with specific properties suitable for effective surveying of medium-wide areas (units to tens of square kilometers per a day). As is obvious from the project name an airship is used as a carrier. This vehicle has some specific properties. The most important properties are high carrying capacity (15 kg), long flight time (3 hours), high operating safety and special flight characteristics such as stability of flight, in terms of vibrations, and possibility to flight at low speed. The high carrying capacity enables using of high quality sensors like professional IR camera FLIR SC645, high-end digital camera and optics in the visible spectrum and tactical grade INSGPS sensor iMAR iTracerRT-F200 and profile laser scanner SICK LD-LRS1000.

The bore-sight calibration of a laser scanner within airborne scanning systems is usually solved by using plane surfaces with unknown spatial parameters like a roof of the building, football playground, parking lot etc. The only presumption is planarity of these objects. The advantage of this attitude is a possibility of using suitable objects in the locality of actual work and thus calibration in the mission. The disadvantage is higher correlation of parameters and therefore higher uncertainty in the computed parameters than if the object parameters are known. Another disadvantage is the uncertainty of planarity degree of chosen objects.

For the stated reasons and because of high intended accuracy of the system AMA it was decided to create a large size calibration field with known spatial parameters like position, normal orientation and degree of planarity and also known accuracy characteristic for these parameters. The field was measured with long range laser scanner Rielg VZ-400 (measurement range: 280m/20% surface reflectivity, accuracy: 5mm/100m) from eight standpoints on the two highest building roofs in the built-up area of Dejvice district in Prague. The size of the area measured in sufficient detail is about 800x700 meters. The scanner positions were determined by static GNSS measurement and registration was realized with fixed scanner positions using natural control objects. 25 most suitable planar surfaces with various normal orientations were chosen after registration and their spatial and accuracy parameters were computed.

The calibration flights were carried out repeatedly to evaluate reliability and accuracy of the achieved results. The mathematical solution, numerical results and theirs standard deviation are presented in this paper.

9245-64, Session PS

The application of remote sensing for climate change adaptation in Sahel region

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The problem of understanding climate change (CC) is one of the major challenges confronting the current and future generations. Despite growing concern, transnational advocacy, and scholarly research, we haven't sufficiently investigated negative environmental and social outcomes as explicated by the deadlock of environmental change. In recent years, there is no doubt that global CC has observable development impacts, which seriously threatens the ability of individuals and communities at all levels. During this process, the clear degradation in the situation of ecosystems has produced a global concern of the urgency to mitigate environmental threats and related impacts. Assessing the impacts and vulnerability of CC requires accurate, up-to-date and improved information. Coupled with the ready availability of historical remote sensing (RS) data, the reduction in data cost and increased resolution from satellite platforms, RS technology appears poised to make great impact on planning agencies and providing better understanding of the dynamics of the climate system, predict and mitigate the expected global changes and the effects on human civilization involved in mapping Land Use Land Cover (LU/LC) at a variety of spatial scales. This research was designed to study the impact of CC in conflict zones and potential flashpoints in Sudan, namely Nuba Mountains, where the community in those area living in fragile and unstable conditions, which making them more vulnerable to the risk of violent conflict and CC effects. And to determine the factors that exacerbate vulnerability in the study area as well as to map and assess the LU/LC change during the period 1984 to 2011 covered the years (1995, 2002 and 2009). Multispectral satellite data (i.e. LANDSAT TM and TERRA ASTER) were used. Three main vegetation indices, namely WDVI, NDVI and SAVI were applied. Change detection techniques were applied to analyze the rate of changes, causal factors as well as the drivers of changes. The main forms of environmental degradation include; resource scarcity, ecosystem degradation, high rate of displacement and migration in addition to destruction of natural forests. The result of the case studies reveals that, the area has been severely hit by recurrent droughts in addition to an intensive and dynamic rate of deforestation. Where the natural vegetation has been removed, modified and replaced mainly by crop fields. The classifications were performed for the imageries from 1984 and 2011, which allowed for an overall assessment of change over the past decade. Cropland area increased approximately to be 142906.9 ha (16.13%) while forest-land decreased to be (15.53%) from (32.6%). Grassland, and bare-land were decreased to (22.58%) and (1.1%), respectively. Relatively, scattered forest areas increased to 22.72% during the time period studied. Recent study showed the importance of spatial variables in tackling CC which promoted the use of maps made within a RS. In addition to provide input for climate models; and thus plan adaptation strategies. In sum, new strategies are needed and research development by advance technique namely RS and GIS to coup all the level of cc.

9245-66, Session PS

Anthropogenic ground deformation observed in Alberta's oil sands by RADARSAT-2 DInSAR

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Ground deformation over oil sand sites in Alberta, Canada, was observed with RADARSAT-2 Interferometric Synthetic Aperture Radar (InSAR). Canadian RADARSAT-2 satellite is capable of acquiring SAR data with 24 day repeat cycle with beams of various resolution, coverage and polarization. In this work we used data from Ultra-Fine 5 beam with resolution 1.6x2.5 m over 20x20 km and Multi Look-Fine 22 with 3.1x4.6 m and 50x50km coverage. We employed the Small Baseline Subset technique for measuring linear deformation rates and time series of deformation when coherence of individual interferograms was favorable. In case of very fast deformation observed at some site the accurate phase unwrapping for a large number of interferograms was not possible so for these areas we computed individual interferograms only.

Alberta's oil sands represent one of the largest deposits of crude oil in the world. They form viscous bitumen embedded within uncemented sand in the Lower Cretaceous McMurray Formation. According to the Energy Resources Conservation Board the main four oil sand deposits widely spread over an area of Northern Alberta, with total initial in-place reserves estimated at about 1.8 trillion barrels. The largest of these deposits is the Athabasca, which outcrops along the Athabasca River and gradually dips down toward the south and west. About 20% of the recoverable bitumen is close to the surface and is accessed through the open pit mining. Extraction of the remaining 80% of deposits, located at depth greater than 65 meters surface mining, is performed using two enhanced oil recovery methods: the Steam Assisted Gravity Drainage (SAGD) and the Cyclic Steam Simulation (CSS). In the SAGD operation a pair of wells separated by a few meters vertically is drilled horizontally into the oil reservoir. Then high pressure steam is injected continuously into the upper well, which heats the oil and reduces its viscosity and causing the heated oil to drain into the lower well, from which it is pumped out. In the CSS operation only one well is drilled, which is periodically used for injection and production. During the injection phase steam is injected for several weeks to months and then flow is reversed and oil is pumped out.

With InSAR we observed ground deformation at both SAGD and CSS sites, but the rate and temporal pattern of deformation was significantly different. At SAGD sites the linear deformation rate measured with SBAS InSAR showed uplift with the maximum rate of about 2 cm/year. Similar rate and temporal pattern was observed at many studied sites. At CSS sites the deformation rate was extremely high showing up to 30 cm of displacements over 24 day cycle or 450 cm/year. Both uplift and subsidence were observed at the same areas during different observation times.

Presented here results suggest that CSS enhanced oil recovery method produces significantly larger ground deformation than SAGD method. Therefore, associate risk and potential impact on the environment and infrastructure can also significantly differ and needs to be studied further.

9245-67, Session PS

CARS: technique for geological exploration of hydrocarbons deposits

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We have previously developed a scanning Raman lidar for automatic remote airborne prospecting, detection and identification of the impurity gas and condensed components in ground layers of an atmosphere and coastal water areas. The small-sized prototype of on board scanning Raman lidar has been manufactured and tested under field conditions of transcontinental gas pipeline. Minimal concentrations were remotely measured for the methane outflow (6 ppm) and the hydrogen suiphide (2 ppm).

In this work, we report on a new generation of the lidar system with improved characteristics for oil-gas exploration and discuss a number of advantages in sensitivity of the remote laser spectroscopy technique and Raman lidar which lead to sufficient applications increase. Our Raman lidar is an active, airborne laser remote sensing instrument with ultraspectral resolution (?/? ? > 1000).

Unlike Raman spectroscopy, CARS employs multiple photons to address the molecular vibrations, and produces a signal in which the emitted waves are coherent with one another. As a result, CARS signal is much stronger than spontaneous Raman emission.

A chamber filled by a mixture of HHG gases and air served as a simulator of hydrocarbon halo. It was irradiated by femtosecond and nanosecond laser pulses. A pump beam (at the frequency referenced ?p) from Ti:Sapphire laser (800 nm, 30 fs, 0,2 mJ, 50Hz) and a probe beam (at the frequency referenced ?pr) from Nd:YAG laser (1064 nm, 8 ns, 60 mJ, 50 Hz) were focused at the chamber. These beams interact with the sample mixture of gases and generate a coherent optical signal at the anti-Stokes frequency (?pr+?p-?S). The anti-Stokes signals (? = 656 nm for CH4 and ? = 658 nm for C3H8) are resonantly enhanced when the frequency difference between the pump and Stokes beams (?p-?S) coincides with the frequency of Raman resonance due to the intrinsic vibrational contrast mechanism.

In order to anayse back scattering anti-Stocks spectral component, we use USB2000 compact optical fiber spectrometer (Ocean Optics) with further numerical processing. Pressure of methane and propane chosen as an indicator of hydrocarbon deposits was ~ 0.01 Torr in 0.2 m-length chamber that corresponds to 10m-thickness of the real halo with concentration at level of 5•E12 cm^-3, i.e. 200 ppb, for each of these gases (fig.2). Since Ti:Sapphire laser has a wide spectrum, the coherent anti-Stock scattering of radiation occurs from corresponding Fourier-components of the pump (? = 800 nm) and Stocks signals (? = 1064 nm)., removed on Stocks shift size of researched gases. Therefore, it was possible to observe an occurrence of the various new components around 650 nm for different heavy hydrocarbon gases (HHG), in the anti-Stock scattering spectrum.

Method CARS allows detection at the level of 3-10 molecules and determines hydrocarbons in the natural atmosphere under the presence of impurities.

We discuss CARS-Lidars ultraspectral devices for solving problems of ecology, for dangerous gases safety programs, detection of the poisonous and explosive substances, as well as a long list of illicit drugs in the agricultural fields.

9245-68, Session PS

Graph-assisted landscape monitoring and pattern analysis

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The structure of computational spatial analysis has mostly built on data where visualization of information takes priority over analysis. In these framings, spatial relationships cannot easily be encoded, hindering spatial analysis that emphasizes how interactions among spatial entities reflect mutual inter-relationships. This research explores how graph theoretic principles and associated mathematical tools can support spatiotemporal analysis by enabling assessment of spatial and temporal relationships in landscape monitoring.

9245-29, Session 8

A comparison of feature selection methods for multitemporal tree species classification

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The problem of feature selection is a significant one in classification problems, where the addition of too many features to the classification fails to lead to significant increases in classification accuracy. This problem is especially significant within the context of multitemporal remote sensing classifications, where the costs and efforts associated with the acquisition of additional imagery can be extensive. In cases where repeated monitoring may be required, as per the monitoring requirements of the EU Habitats Directive, it would thus be beneficial to identify the most important seasons for acquiring imagery for specific land cover types. This study uses a phenologically-adjusted 21 date RapidEye time-series between 2009 and 2013 from a forested area in northern Germany in order to evaluate two methods of feature selection. The two existing methods of feature selection compared in this study are: (i) a genetic algorithm approach (GA), (ii) and a semi-exhaustive approach (EXH), both of which compare permutations of sequential date and band combinations. The GA is an active search method, while the EXH is a passive (randomized) approach. These methods are employed using a seven class support vector machine classification on the full dataset of five bands per date, and the Normalized Difference Vegetation Index (NDVI). Overall accuracy (OAA) is used as the performance metric, and significance is assessed using the p-value from the McNemar test. The results from the feature selection methods are compared on the basis of phenological seasons selected across all iterations and the ideal number of combinations, based on the ratio of better performing classifications to all other classifications. The initial results comparing the feature selection methods on the NDVI dataset suggest that there is a significant shared preference towards full spring/early summer for image acquisition, and partial agreement for other seasons. The EXH determined that there were twice as many significant features compared to the GA, though with both methods some of these features could be aggregated by phenological season. Using the best selected features, the GA achieved 0.84 OAA and the EXH achieved 0.91, with the GA features being a subset of those selected by the EXH. However, a minimum of four features is required to reach at least a 0.8 OAA for both methods, using images from full spring/early summer and early/late fall, though the EXH places additional emphasis on early spring over fall.

9245-30, Session 8

Monitoring land use /land cover dynamics in northwestern Ethiopia using support vector machine

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Land use/land cover (LULC) change assessment explores a terrestrial ecosystem in relation to the impact of natural processes and anthropogenic activities towards temporal and spatial change. This study explores spatial and quantitative dynamics of land use change in the semi-arid regions of northwestern Ethiopia.

Landsat-5 Thematic Mapper (TM) of 1984 and Landsat-8 Operational Land Imager (OLI) of 2014 acquired during the dry period were used for this study.The imagery was processed using Environment for Visualizing Images (ENVI version 5.0) and ArcGIS 10 software packages. The OLI 2014 image was geometrically rectified to the UTM coordinate zone 37 North, Spheroid Clarke 1880, Datum Adindan using control points collected from topographic maps of the study area. An image to image registration was applied between TM 1984 and OLI 2014 imagery using the nearest neighbour algorithm. The root mean square error (RMSE) is between 0.3 to 0.5 pixels. All bands 1-5 and 7 of TM imagery and bands 1-7 of OLI were used for extracting biophysical features. 650 stratified random reference points and their attributes were collected using Google Earth for ground-truthing and for accuracy assessment of classified imagery. Radiometric calibration and atmospheric correction were carried out to correct for changes in scene illumination, atmospheric and solar condition, viewing geometry, and instrument response characteristics. Supervised classification algorithm using support vector machines (SVM) was used to map and monitor land use transformations. Among the SVM kernels, we used the Gaussian radial basis function kernel (RBF) for mapping and change detection assessment. The Library for Support Vector Machines (LIBSVM) program developed by Chang and Lin (2001) was used for classification. The model was parameterized using the training samples for each land use type. A cross validation test was applied combining ? and C to obtain optimum values of these parameters. A classification accuracy assessment was performed based on 250 training samples using stratified random sampling representing the five land use classes. A confusion matrix was developed based on the comparison of selected samples of the classified imagery with the ground sampling. In this process an overall accuracy, producer and user accuracies and kappa coefficient were calculated for the time series classification results.A post-classification change detection assessment was applied to individual image classification outputs of the best performing SVM model in order to identify respective two-date change trajectories. The classified imagery of 1984 and 2014 revealed a significant increase in cropland from 8.26 % to 53.3 % and a decline in woodland coverage from 81.08 % to 31.03 % respectively. Post-classification comparisons of the classified imagery identified a major woodland transformation to cropland which is attributed to population size and economic activity. This significant land use transformation is due to accelerated human impact and subsequent agricultural land expansion. The agricultural expansion is related to population growth and higher demand of oil crop from the region. It needs due attention to reduce the rate of land transformation and subsequent changes to ecosystem for sustainable agricultural production in varying semi-arid climatic conditions.

9245-31, Session 8

Integration of Marked Point Processes and Template Matching for the identification of individual tree crowns in an urban and a wooded savanna environment in Brazil

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A number of methods have been developed for the automatic identification and delineation of individual tree crowns from high spatial resolution satellite image to provide support for the management and maintenance of forests both in natural and urban environments. In this paper we present a method that integrates a Marked Point Process (MPP) model and Template Matching (TM) to extract individual tree crowns in two tropical environments. The MPP is an extension of Markov random fields in which objects are defined by their position within a space of possible positions and their marks (e.g. shape). The MPP has been increasingly used for the recognition of objects in high

resolution satellite images, but most implementation use an oversimplified model as mark such as circles or squares with a single brightness value. We argue that the MPP could take better advantage of the geometry of trees by incorporating a three-dimensional model as a mark. Conversely, TM is an approach to pattern recognition that takes the characteristics of the objects into account. Our method uses metrics of autocorrelation and distribution for determining which objects have been correctly targeted by the MPP. The autocorrelation between the illuminated 3-D crown model and the image is an inheritance from TM. The methodology was applied in sub-images of the WorldView satellite in two different contexts in Brazil: urban and wooded savanna environments. Synthetic tree crowns were generated using a dome shape and a slightly modified Lambertian reflection model. The MPP starts with a birth phase, where crowns of random radiuses (within a pre-defined interval) are inserted at random coordinates within a space not already filled with crowns while allowing some degree of overlap. Once all crowns have been assigned, the autocorrelation between the model and the corresponding portion of image is computed. The objects are then sorted by their autocorrelation value. The object with the largest value is preserved and the remainder is eliminated (death phase). Additionally, the overall distribution of crown pixel values is updated at the end of each iteration. The process seeks to minimize the overall energy which combines the variance of the spectral distribution and the inverse of the autocorrelation. All trees are considered "found" when the energy stabilizes or the maximum number of iteration is reached. At the final phase, all objects are re-evaluated by comparing them with all tree crowns of different radiuses. The results are validated by counting the correctly identified trees and by comparing their size with our interpreted version. Results are encouraging with approximately 60 to 80% of correctly identified trees depending on the context. The most difficult cases are related to the quantity of other objects such as houses in the scene, the uneven distribution of trees and strong variations of the background.

9245-32, Session 9

Scale issue and hierarchical GEOBIA for mapping land use/land cover

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For simplicity sake, we use the term 'scale' referring to the spatial resolution, although it is worth mentioning that image scale has additional components. In most of previous studies, when studying the issue of scale, scientists were only investigated a specific geographical environment (a scene), such as a forest land, an urbanized zone, or an agricultural fields. They were searching for the most appropriate unique spatial resolution for their particular concern. It was rarely considered that the scene was composed of different sized real-world entities, and that a single resolution might not be appropriate to discriminate all classes within the image. Moreover, due to complexity and spectral similarity in many areas, Land Use/Land Cover (LU/LC) mapping with remotely sensed data encounters serious problems when applying methods based on spectral information and ignore spatial and contextual properties. Fine spatial resolution imagery is assumed to provide detailed attribute characterizations, meanwhile within class variances of spectrum is subsequently increased, which leads to confused result in most cases. Therefore, an implicit assumption of the Geographic Object Based Image Analysis (GEOBIA) literature is that the analysis and classification based on contiguous segmented homogeneous pixels (i.e. image objects) is more accurate than pixel-based methods for high spatial resolution, since the objects efficiently suppress this local variability in the final thematic map product. However, the questions arises whether GEOBIA is inherently more precise at fine spatial resolution than coarser scale, and how both pixel-based and GEOBIA approaches compare in relative precision as a function of spatial resolution. This paper investigates these assumptions within the context of a case study of LU/LC classification system for use with optical multispectral satellite data in Blue Nile region of Sudan. The classification scheme intended to generate nine LU/LC classes i.e.; agriculture, bare-land, crop-land, dense-forest, grassland, orchard, scattered-forest, settlements and water body. A RapidEye scene data of 2010, with 5 meter spatial resolution, was used for the analysis. The image was classified using both maximum likelihood as a common method of pixel-based and GEOBIA. The results were compared with the classified maps of coarser resolution achieved from Terra Aster image data, with 15 meter spatial resolution, utilizing the same spectral regions, unique approaches and identical set of training samples. Field survey validation points were implemented to assess the quality of results achieved based on confusion matrices. As anticipated, this work emphasized that the GEOBIA approach is proposed to be an advanced solution for image analysis, since the accuracies were improved at different scales applied compare with those of pixel-based approach. Meanwhile, the results reported for the two approaches were consistently high at the finer spatial resolution, and much significantly enhanced with GEOBIA. Consequently, we discussed the characteristics of the hierarchical ecosystem of LU/LC classifications based on the different spatial resolutions of the image sensors utilized.

9245-33, Session 9

Mapping tree species in a boreal forest area using RapidEye and Lidar data

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One of the issues related to a successful implementation of a cumulative effects management system in Alberta is land reclamation. Based on Alberta's Environmental Protection and Enhancement Act " the objective of reclamation of Specified Land is to return the land to an equivalent land capability (ELC)" where ELC corresponds to the ability of the reclaimed land to support various land uses, similar to the land ability prior to exploitation activities but without being necessarily identical. Reclaimed lands include oil and gas pipelines as well as wellsites and associated facilities such as access roads which are small and narrow features ranging from few to about a hundred of meters. One of the main criteria of relevance for land reclamation monitoring is vegetation species.

The scope of this paper is to assess the use of RapidEye alone and in combination with LiDAR data for mapping forest species. Three main questions were identified in this work including:

1) How well tree species can be mapped using RapidEye alone and combined with LiDAR data?

2) How sensitive is the classification accuracy to the type of classifier used?

3) How does the LiDAR acquisition date affect the classification accuracy?

This work was conducted using a study area located near Cold Lake, Alberta, situated 300 km northeast of Edmonton where a field campaign was conducted in July 2012. The area is covered by boreal forest with major tree species including trembling aspen, spruces, tamarack and balsam popular.

The five RapidEye surface reflectances in addition to the red-edge NDVI were used in the classification process. In addition, two sets of LiDAR data acquired in 2006 and the 2012 over the

study area were processed using the FUSION/LDV software and separately incorporated in the classification process. Using all LiDAR returns, the percentages of returns above a predefined set of height-break values ranging from 1.4 to 21.4 m using a 2-m step were calculated within a five-meter cell to stratify the canopy structure profile. In addition, average intensity, terrain slope and aspect were also derived at 5-meter resolution.

A landcover classification was first produced using RapidEye data to build a mask of forested areas. Tree species classification was then performed on the forested areas for the following species: Trembling Aspen, Tamarack, Balsam Poplar, Black Spruce, White Spruce, and Jack Pine.

The Support Vector Machine (SVM) and Random Forest decision tree (RF) classification methods were assessed for mapping tree species. Reference samples were selected from the 2012 field data and the Alberta Vegetation Inventory Database (AVI) to be used for training and validation of the data classification.

Accuracy assessment results showed that the overall accuracy was significantly higher when combining LiDAR and RapidEye. Compared to SVM's, overall classification accuracy was more than 12% higher for RF. Similar results were observed for user's and producer's accuracies showing an increment ranging between 7% and 32 % .

Accuracy assessment results associated with the use of LiDAR data acquired at different dates showed a moderate difference in overall accuracy. Increment in accuracy values between 3% and 12 % was observed in producer's and user's accuracy.

9245-34, Session 9

Tracking sugarcane expansion in the Sao Paulo region through Landsat and Envisat/ERS time-series

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Favourable national policies and consistent market opportunities in the production of bio-ethanol in Brazil determined over the last decade an impressive development of the sugarcane agri-business, especially within those areas of the country with high environmental and infrastructures suitability. Among these, the south-central part of Brazil, led by the state of Sao Paulo, experienced a dramatic increase in sugarcane acreage, stepping from 4 Mha (million hectares) in 2002 to 7 Mha in 2008. As a result, large-scale land use change (LUC) dynamics occurred, most significantly involving pastures and other cultivars being replaced by sugarcane. It is evident that the possibility of accurately quantifying such LUC in space and time through remote sensing would greatly benefit environmental, economic and social impact analysis.

With such concern in mind, we propose a satellite data assimilation solution aimed to identify and characterize the LUCs phenomena. The devised method performs an automated classification and temporal tracking of sugarcane, hence opposed to the time-consuming qualitative approaches so far applied to the area. The technique makes use of all the available cloud-free Landsat TM and ERS/ENVISAT SAR C-band (in stripmap mode) time series to recover LU information at per-pixel level (30m from Landsat sensor) within the time span from 2003 to 2011. A suited set of indicators was conceived for both sensors upon proper analysis of the spectral profiles of the different LU classes. Their fitness was assessed for different data configurations in terms of acquisition sparsity, as demanded by the high heterogeneities in temporal sampling. The spatio-temporal information was then assimilated by means of a Markov Random Field model. The labeling approach has been indeed designed to make effective use of the sugarcane temporal pattern, i.e. to exploit the permanent nature of the crop. The approach has been analysed in depth on two representative municipalities in the northern region of the Sao Paulo state, where an acreage expansion larger than 200% has taken place starting from 2003. The dataset comprises a set of 64 ENVISAT/ERS acquisitions, mostly in VV polarization, and a set of 80 Landsat 4/5 images. Preliminary cross-comparison results with the available maps based on qualitative assessments from INPE show good consistency, revealing indeed a constant yearly growth of sugarcane away from the local mill facility.

9245-35, Session 9

Deriving phenological metrics from NDVI through an open source tool developed in QGIS

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Vegetation indices have been commonly used over the past 30 years for studying vegetation characteristics using images collected by remote sensing satellites. One of the more commonly used is the Normalized Difference Vegetation Index (NDVI), which is computed as (NIR-Red)/(NIR + Red), where NIR and Red are respectively the near-infrared and red sensor bands. The various stages that green vegetation undergoes during a complete growing season can be summarized through time-series analysis of NDVI data [1]. The analysis of such time-series allow for extracting key phenological variables or metrics of a particular season. These characteristics may not necessarily correspond directly to conventional, ground-based phenological events, but do provide indications of ecosystem dynamics. A complete list of the phenological metrics that can be extracted from smoothed, time-series NDVI data is available in the USGS online resources (http://phenology.cr.usgs.gov/methods_deriving.php).

This work aims to develop an open source application to automatically extract these phenological metrics from a set of satellite input data. The main advantage of QuantumGIS (QGIS) for this specific application relies on the easiness and quickness in developing new plug-ins, using Python language, based on the experience of the research group in other related works [2]. QGIS has its own application programming interface (API) with functionalities and programs to develop new features. The toolbar developed for this application was implemented using the plug-in NDVIToolbar.py. The user introduces the raster files as input and obtains a plot and a report with the metrics. The report includes the following nine metrics: SOST (Start Of Season – Time) corresponding to the day of the year identified as having a consistent upward trend in the NDVI time series; SOSN (Start Of Season – NDVI) corresponding to the NDVI value associated with SOST; EOST (End of Season – Time) which corresponds to the day of year identified at the end of a consistent downward trend in the NDVI time series; EOSN (End of Season – NDVI) corresponding to the NDVI value associated with EOST; MAXN (Maximum NDVI) which corresponds to the maximum DNDVI value; MAXT (Time of Maximum) which is the day associated with MAXN; DUR (Duration) defined as the number of days between SOST and EOST; AMP (Amplitude) which is the difference between MAXN and SOSN; and TIN (Time Integrated NDVI) which is the daily (interpolated) integration of NDVI above the baseline for the entire duration of the growing season [1]. This application provides all these metrics in a single step. Initially, the data points are interpolated using a spline through the function UnivariteSpline, of the scipy library. The nine metrics previously described are then obtained from the spline using numpy functions. In the present work, the developed toolbar was applied to MODIS data covering a particular region of Portugal, which can be generally applied to other satellite data and study area. The code is open and can be modified according to the user requirements. Other

advantage in publishing the plug-ins and the application code is the possibility of other users to improve this application.

[1] Reed, B.C., "Trend analysis of time-series phenology of North America derived from satellite data," GIScience and Remote Sensing, 43 (1): 24-38 (2006).

[2] Teodoro, A.C. and Duarte, L., "Forest fire risk maps: a GIS open source application–a case study in Norwest of Portugal," International Journal of Geographical Information Science. Vol. 27, Issue 4, 699-720 (2013).

9245-37, Session 10

Web service tools in the era of forest fire management and elimination

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Fires in forests and forested areas in South Europe, North America, Central Asia and Australia are a diachronic threat with major critical ecological, economic and social impacts. During the last decade the frequency, the magnitude and the intensity of the forest fires have been increased even more as a consequence of the ongoing climate change and the degradation of natural resources in the "altar" of human's need for material possession. An effective response to such disasters requires an effective planning, with emphasis on the early detection of the ignition area of the fire and the accurate prediction of fire propagation to support the rapid response mechanisms, like the Forest Management authorities and Regional Civil Protection agencies. For this purpose, an information system which will have the ability to predict and visualize the behavior of the fire could be an invaluable tool during the phase of fire mitigation. If this system has also the capability to perform simulations in order to evaluate scenarios, based on real time weather conditions or on weather forecast data, it will become a valuable decision support tool during the planning phase. Under the framework of FLIRE (Floods and Fire risk assessment and management- LIFE11ENV/GR/975), which is a LIFE+ co-funded by the European Commission research project, such an information system has been (among others) developed and presented in this study. FLIRE DSS has been developed as a web-based application, in which the end-user can have access in real time via any web browser from any platform (PC, Laptop, Tablet, Smartphone). The only requirement for this tool is the ability to connect to a specific website by using 3G cellular network or a Wi-Fi connection. This application use forest fuel maps which have been developed by using generalized fuel maps (ArcFuel), updated landcover dataset by analyzing ALOS AVNIR, Landsat OLI and aerial color images as well as in-situ observations. Also, leverages data from meteorological stations and weather forecasts from numerical models to feed with the necessary data for the calculations the fire propagation model, which acts as a web service and to visualize the prediction of the model for the given by the user time period. For security reasons, as such information is crucial and sensitive, only authorized users can have access to the system as well as to the results of the simulations.

9245-39, Session 10

A study on wildfires using satellite data over the Korean Peninsula

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Nowadays, forest fires occur with frequency and has tend to grow the size. The phenomenon such as an rise in temperature and decrease in rainfall was observed in South Korea with similar tendency as the whole world. And South Korea has tend to increase the number of occurrence of forest fires. The ratio of coniferous forests which are relatively combustible in comparison with other species of trees was 40%. a big forest fire can be possible to occur easily in this condition if the fires fail to be extinguished in the early stages. The area of forests is very large and natural disaster including wildfires is hard to predict. So continuous observation is needed. Satellite remote sensing technique can detect broad extent continuously and a useful tool to detect occurrence of fires. This study used 4-micrometer and 11-micrometer brightness temperature to detect fire pixels. Fire pixels of satellite images have higher values in 4-micrometer brightness temperature than 11-micrometer brightness temperature. In order to detect fire, we select potential fire pixel using threshold firstly. and We then select fire pixel more precisely through comparing statistics between selected potential fire pixel and background window. finally, We eliminate false alarm from result. false alarm occur mainly due to sun glint reflection, desert and coastal. In case of KOREA, sun glint reflection can occur mostly than other things. false alarm by sun glint occur if angle between sun reflection and satellite location is almost same. We eliminate false alarm of sun glint through calculation by using sun and sensor zenith angle, relative azimuth angle. Our algorithm was training to improve detection accuracy for wildfires using data on Aprill 1-2, 2011. So as to validate our algorithm result data was used on March 9, 2013. We verified the result of our fire detection algorithm using statistical data of Korea Forest Service and ASTER(Advanced Spaceborne Thermal Emission and Reflection Radiometer) image.

Wildfire information may be useful to citizen because fires do much damage in our life. Smartphone application can be a useful tool which offer information of fires.

We finally developed smartphone application using hybrid-method.

Hybrid-smartphone application can reduce the cost which makes application because HTML5 is used to develop application. Three functions were developed including query by date, recent and surrounding fire search. In order to estimate damaged area or loss cost after occurrence of fires, CVA(Change Vector Analysis) method is needed in the future works.

9245-40, Session 10

Remotely Piloted Aircraft Systems (RPAS) for high resolution topography and monitoring: civil protection purposes on hydrogeological contexts

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The proposed work concerns the analysis of Remotely Piloted Aircraft Systems (RPAS) on hydrogeological contexts for civil protection purposes, underlying the advantages of using a flexible and relatively low cost system. The capabilities of photogrammetric RPAS multi-sensor platform were examined in term of mapping, creation of orthophotos, 3D models generation and data integration into a 3D GIS (Geographic Information System). The RPAS used (multirotor OktoXL, of the Mikrokopter) was equipped with a GPS (Global Positioning System) receiver, different digital cameras for photos and videos, an inertial navigation system, a radio device for communication and telemetry, etc. This innovative way of viewing and understanding the environment showed huge potentialities for the study of the territory, but due to its characteristics could not be substituted to classic aircraft surveys. However, such characteristics seems to give priority to local applications for rigorous and accurate analysis, while it remains a means of expeditious investigation for more extended areas.

Specifically, the experimentation was performed in this way: i. initial study of the system, together with flight simulations to familiarize with flight operations for landing, take-off and free flight; ii. examination of the Italian Civil Aviation Authority (ENAC- Ente Nazionale per l'Aviazione Civile) regulations; iii. flight tests, both manual and scheduled, with and without load and with different loads, in restricted area for security; iv. flights in operative context of hydrogeological risk (unstable slopes and river catchment areas); v. data processing with different software (APS -Menci software-, Photoscan -Agisoft-) and different strategies; vi. validation of results with GPS, ALS (Airborne Laser Scanner), TLS (Terrestrial Laser Scanner) data and aerial images; vii. 3D GIS for the integration of multi-source spatial data.

According to civil protection purposes, the experimentation was carried out by simulating operational protocols, for example for inspection, monitoring, land mapping, extraction of 2D and 3D information, data georeferencing, DTM/DSM (Digital Terrain Model/Digital Surface Model) generation and data integration with GIS platforms.

Experimentation were performed on areas threatened by hydrogeological risk for people, houses, infrastructure of transport and areas of natural interest (i.e. Rete Natura 2000).

Flights were planned on scheduled waypoints and trajectories in order to optimize the image quality (pixel dimension, focus, optics, illumination, etc), the image overlap (along track 80% and across track 60%), the flights capabilities (time and height) and the coverage of the investigated area.

Regarding the data processing, different image processing methods were performed: structure from motion algorithms, photogrammetric processing, self-calibration strategies and lens calibration are only some examples. Furthermore, for the georeferencing, tests were carried out on the use of GCP (Ground Control Points), on smoothed GPS trajectories and on reference frame transformation.

The validation of results (with others techniques such GPS, ALS and TLS) and the integration into a 3D GIS were an important step of the work, considering that only accurate, precise, trusted, reliable and accessible information should be the starting point of informed actions.

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9245-41, Session 10

Multipurpose use possibility of Zagros forest areas using GIS, RS and AHP

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Degradation of Zagros forests has continued since the distant past because of traditional and often inaccurate forest exploitation due to poverty, unemployment and livelihood. In this study, to reduce forest degradation and improve stability, assessment of multipurpose use of Zagros forest areas was done using Geographical Information System, Remote Sensing and Analytical Hierarchy Process. About 10,000 hectares of Baneh city forest were surveyed. of possible land uses as well as their criteria and sub criteria were identified based on expert's judgment. Sub criteria maps were created using existing data, the field work and satellite images. Weights of criteria and sub criteria were determined using analytic hierarchy process. Values of sub-criteria were classified, and each class was rated according to expert judgment. Priority maps of all land uses were produced with a weighted linear combination method, using geographical information system. The final priority map was achieved by overlying of the individual land use priority maps. The final ecological suitability map was prepared by editing the priority map. The results show that the various land uses can exist separately or together in the forest. Following the proposed land use would reduce people's dependence on the forest trees, reduce damage and improve forest sustainability.

9245-43, Session 11

Prediction of Interdecadal variation in climate over NE China with countermeasures

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The study shows that about 1.40C rise in mean temperature occurs between the 1900-1910s and 1980-1990s, with an abrupt change around 1990 due to climate shift. Warming, leading to extreme minimum temperature rise, smaller annual range. Analysis of the facts of climate change, We also notice that the rise is 1.60C in winter, reaching roughly 1.30C in spring, and 0.60C (0.40C) in summer (autumn). Nationwide, The most significant regional warming in Northeast China,the strongest warming is found in the northern par of NE China ,while in the boreal hemisphere the warming center of eastern Asia is in Siberia. Comparison of the temperature change in the last century over the boreal hemisphere and NE China yields that the trends and cold/warm periods are more consistent for both the regions , Respectively, the three warm periods were experienced at the beginning of the last century, 40's, 80's,while the cold period in between several warm periods.It is worth noting that from the 1980s to present day the climate remains to be in warming, a phenomenon that has never happened in the last century.

5-model predictions of NE China climate for the future 30-50 years indicate a higher temperature rise in the year 2030 and 2050. The yearly mean would be the 1.940C rise in 2030, with 2.06, 1.26, 1.79 and 2.660C increase in spring, summer, autumn and winter, respectively. These results suggest that the highest increase is in winter, followed by the rise in spring, autumn and summer, in order. The temperature increase is higher in the northern than in the southern part. The increase is expected to be kept in 2050, with annual mean rise of 2.420C, with the ascent of 2.13, 1.68, 2.56.and 3.210C, respectively in spring,

summer, autumn and winter. The winter rise is the strongest, Followed by the autumn, spring and summer. centered on the northern part of the region. Reference to the relevant papers shows that warming centers in Siberia region.a conclusion that is similar to that derived in our study (1990) concerning the warming for the past century, which demonstrates the regional warming in future five decades would follow the law of the last century.

Based on the above findings, the cumulative temperature band of T≥100C for crop growth would be shifted northward by approximately 5 latitudes. In 2050 the original first band would move to the north of the Daxinganling mountains and the other 4 bands be nearly eliminated. The dominant farming area of rice would be shifted into the Heilongjiang valley, the winter wheat zone be expanded for experiment, the maize cropping zone should be expanded for forage and cash purpose. Climate warming is greatly beneficial to soybean crop, its high-yield band would be displaced northward, leading to its markedly increased yield, and the cultivation of chinophilous crops would be spread northward. For this purpose 6 countermeasures are proposed for the structure of staple grain crops and the necessary adjustment of their regional distribution for the stable and high yields of crops in this region.

9245-44, Session 11

Use of Landsat data to create a time-series of sand dune fields maps in Abu Dhabi, United Arab Emirates

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Up to 90% of the United Arab Emirates' (UAE) surface is covered by sand dunes and intervening inter-dune belts. The country is severely affected by problems related to sand dunes movement and aeolian deposits, recognized as a major contributor to desertification. This study discusses the use of publicly available Landsat TM and ETM+ data to detect sand dunes fields and enable monitoring of their movements in the Emirate of Abu Dhabi, UAE. The study focuses on developing a classification approach and applying it to historical Landsat data to produce consistent Land cover maps useable in subsequent change detection studies.

Landsat scenes acquired over the period 1972 - 2012 are used to evaluate different multispectral classification approaches and determine the accuracy of resulting maps. The methodology uses several configurations of supervised classification techniques that include different band combinations to determine those that produce the highest accuracy in mapping the predominant land cover classes in the area: Sand dunes, Sand sheets, Urban, Vegetation, Sabkhas, Limestone and Water. Preliminary results of applying these approaches indicate that the use of Principal Components as input to the classification algorithm leads to improved detection accuracy. However, all methods used exhibit a certain level of confusion between sparse vegetation and other classes. The use of a vegetation index as a discriminator helps improve the classification accuracy.

To facilitate the use of resulting classification maps in change detection studies aiming at assessing and modeling sand dunes movement, a geodatabase is built containing resulting layers for further GIS analysis.

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9246-1, Session 1

Airborne 2-micron double-pulsed integrated path differential absorption lidar for column CO2 measurement *(Invited Paper)*

Upendra N. Singh, Jirong Yu, Mulugeta Petros, NASA Langley Research Ctr. (United States); Tamer F. Refaat, Old Dominion Univ. (United States); Ruben G Remus, James J Fay, NASA Langley Research Ctr (United States); Karl D. Reithmaier, Science Systems and Applications, Inc. (United States)

Double-pulse 2-micron lasers have been demonstrated with energy as high as 600 mJ and up to 10 Hz repetition rate. The two laser pulses are separated by 200 μs and can be tuned and locked separately. Applying double-pulse laser in DIAL system enhances the CO2 measurement capability by increasing the overlap of the sampled volume between the on-line and off-line. To avoid detection complicity, integrated path differential absorption (IPDA) lidar provides higher signal-to-noise ratio measurement compared to conventional range-resolved DIAL. Rather than weak atmospheric scattering returns, IPDA rely on the much stronger hard target returns that is best suited for airborne platforms. In addition, the IPDA technique measures the total integrated column content from the instrument to the hard target but with weighting that can be tuned by the transmitter. Therefore, the transmitter could be tuned to weight the column measurement to the surface for optimum CO2 interaction studies or up to the free troposphere for optimum transport studies. Currently, NASA LaRC is developing and integrating a double-Pulsed 2-μm direct detection IPDA lidar for CO2 column measurement from an airborne platform. The presentation will describe the development of the 2-μm IPDA lidar system and present the airborne measurement of column CO2 and will compare to in-situ measurement for various ground target of different reflectivity.

9246-2, Session 1

Mobile DIAL system for multipurpose measurements of CO2 concentration using 1.6?m direct detection technique

Chikao Nagasawa, Yasukuni Shibata, Makoto Abo, Tokyo Metropolitan Univ. (Japan)

Modeling and simulation of budget of the CO2 flux from the terrestrial ecosystems such as forests and grassland and the CO2 emission from plants are useful for global climate changes prediction. The model output has been validated by comparisons with atmospheric CO2 observational data around the sink and source using monitor towers with direct measuring instruments and measuring instruments dispersed on the ground. Moreover the accurate vertical CO2 profiles in the atmosphere are highly desirable in the inverse techniques to improve quantification and understanding of the global budget of CO2 and also global climate changes. Aircraft instruments can measure vertical profiles up to an altitude of about 10km but cannot perform spatiotemporal distribution measurements of atmospheric CO2. Therefore differential absorption lidar (DIAL) is an attractive method for obtaining the distribution of CO2 concentration around ecosystem and vertical CO2 profiles.

The 1.6 –m DIAL measurement of the vertical CO2 profile was already achieved successfully up to 7 km altitude with a random error less than 1.0 % by integration time of 30 minutes and range resolution of 300 - 600 m by our system. We report the multi-purpose 1.6 ?m DIAL system installed in the mobile container for measurements of spatiotemporal CO2 concentration distributions and/or CO2 vertical concentration profiles. Moreover, a few algorithms for derivation processing of vertical concentration profiles from received signals of CO2-DIAL are also discussed for improvement of measurement accuracy.

This work was financially supported by the System Development Program for Advanced Measurement and Analysis of the Japan Science and Technology Agency.

9246-3, Session 1

High repetition rate Ho:YLF laser for space-borne lidar applications

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The study of global warming requires the precise and accuracy measurement of greenhouse gases concentrations in the atmosphere from space. Integrated Path Differential Absorption (IPDA) lidar is a new approach for global observation of atmospheric carbon dioxide to achieve the unprecedented accuracy. It needs a highly efficient and high repetition laser as the transmitter due to the limited power, volume, and weight. For the direct detection IPDA lidar, the desired 2 ?m Ho:YLF laser should generate 34-40 mJ pulses at the repetition rate of 100 to 200 Hz, with short pulse length (<100 ns) and limited power supply (<800 W). In-band pumped Ho:YLF laser has high efficiency and the ability to operate in high repetition rate (>1 kHz).

Supported by NASA's Earth Science Technology Office (ESTO) Advanced Components Technology (ACT) program, a single transverse/longitudinal mode, compact Q-switched Ho:YLF laser has been designed and demonstrated at Langley Research Center, where a 40 W Tm:fiber is used as the pump source. The output pulse energies from oscillator are 40 mJ for 100 Hz operation and 34 mJ for 200 Hz operation, respectively. The higher efficiency of 200 Hz operation than that of 100 Hz one is owing the upper level lifetime of Ho:YLF crystal (~14 ms). The peak power exceeds 1 MW corresponding to 32 ns pulse. The near diffraction-limited beam and transform-limited pulse have been measured. Such a laser can be packaged in a 4 x16 inch enclosure to make it compact and robust.

9246-4, Session 1

Satellite assisted aerosol correlation in a sequestered CO2 leakage controlled site

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Currently one of the main challenges in CO2 storage research is to grant the development, testing and validation of accurate and efficient Measuring, Monitoring and Verification (MMV) techniques to be deployed at the final storage site, targeting maximum storage efficiency at the minimal leakage risk levels. For such task a mimetic sequestration site has been deployed in Florianopolis, Brazil, in order to verify the performance of monitoring plataforms to detect and quantify leakages of ground injected CO2, namely a Cavity Ring Down System (CRDS) - Los Gatos Research - an Eddy Covariance

System (Campbell Scientific & Irgason) and meteorological tower for wind, humidity, precipitation and temperature monitoring onsite. The experimental campaign carried on was performed for almost a month during September 2013, when a period of pre-injection of 10 days was used as short term background measurement, a injection period when industrialized CO2, with known isotopic composition was employed followed by 5 days of post injection. The results show an average CO2 concentration of 390(20) ppm and a delta-13 VPDB value of – 18 per mil, when leakages events were considered CO2 concentrations were over 600 ppm daily and delta-13 values reached about 28 per mil. The measurement strategy for detecting CO2 leakages can be very challenging since environmental and phytogenic influence can be very severe and play a role on determining if the values measured are unambiguous or not. One external factor to be considered is the amount of incoming solar radiation which will be the driving 'force" for the whole experimental setup and following this reasoning the amount of aerosols in the atmospheric column can be a determinant factor influencing the experimental results. Thus the investigation of measured fluxes CO2 and its concentration with the aforementioned experimental instruments and their correlation with the aerosol data should be taken into account by means of satellite borne systems dedicated to measure aerosol vertical distribution and its optical properties, in this study we have selected CALIPSO and MODIS instrumentation to help on deriving the aerosol properties and CO2 measurements. The diurnal variations of satellite retrieved aerosol parameters and CO2 measured at the experimental site show some correlation but we had to use some non-parametric statistical approach since the onsite sampling time are quite different from the observation cycles given by the spaceborne equipment and short term and frequency averaging might carry instrumental trends which are not meaningful for the CO2 cycle in the experiment. The Aerosol Optical Depth (AOD) and its distribution were extracted from MODIS and CALIPSO, respectively. A total of 6 overpasses were available during the campaign period and their correlation with the CO2 measurements show a discrete influence. In fact the aerosol present in the atmosphere modulates the solar radiation present in the site affecting all the ecosystem and geochemical cycle in the experiment. There are future strategies and instrument which should be brought onsite for helping us to understand these cross correlations between atmospheric and geophysical

9246-19, Session 1

Laser energy monitor for double-pulsed 2-micron IPDA lidar application

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Integrated path differential absorption (IPDA) lidar is a remote sensing technique for monitoring different atmospheric species. The technique relies on wavelength differentiation between strong and weak absorbing features normalized to the transmitted energy. 2-micrometer double-pulsed IPDA lidar is best suited for atmospheric carbon dioxide measurements. In such case, the transmitter produces two successive laser pulses separated by short interval (200 micro-second), with low repetition rate (10Hz). Conventional laser energy monitors, based on thermal detectors, are suitable for low repetition rate single pulse lasers. Due to the short pulse interval in double-pulsed lasers, thermal energy monitors under estimate the total transmitted energy. This leads to measurement biases and errors in double-pulsed IPDA technique.

In this paper, the design and calibration of a 2-micrometer double-pulse laser energy monitor is presented. The design is based on a high-speed, extended range InGaAs pin quantum detectors suitable for separating the two pulse events. The design includes a pulse integration technique for converting detected pulse power into energy. Results are compared to a photo-electro-magnetic (PEM) detector for impulse response verification. Calibration included comparing the three detection technologies in single-pulsed mode, then comparing the pin and PEM detectors in double-pulsed mode. Energy monitor linearity will be addressed.

9246-5, Session 2

A new technique for the retrieval of near-surface water vapor using DIAL measurements and its validation *(Invited Paper)*

Syed Ismail, NASA Langley Research Ctr. (United States); Susan Kooi, Science Systems and Applications, Inc. (United States); Richard Ferrare, David Winker, Johnathan W. Hair, Amin Nehrir, Chris Hostetler, NASA Langley Research Ctr. (United States)

Water vapor is one of the most important atmospheric trace gas species and influences radiation, climate, cloud formation, surface evaporation, precipitation, storm development, transport, dynamics, and chemistry. For improvements in NWP (numerical weather prediction) and climate studies, global water vapor measurements with higher accuracy and vertical resolution are needed than are currently available. Current satellite sensors are challenged to characterize the content and distribution of water vapor in the Boundary Layer (BL) and particularly near the first few hundred meters above the surface within the BL. These measurements are critically needed to infer surface evaporation rates in cloud formation and climate studies. The NASA Langley Research Center Lidar Atmospheric Sensing Experiment (LASE) system, which uses the Differential Absorption Lidar (DIAL) technique, has demonstrated the capability to provide high quality water vapor measurements in the BL and across the troposphere. A new retrieval technique is investigated to extend these DIAL water vapor measurements to the surface. This method uses signals from both atmospheric backscattering and the strong surface returns (even over low reflectivity oceanic surfaces) using multiple gain channels to cover the large signal dynamic range. Measurements can be made between broken clouds and in presence of optically thin cirrus. Examples of LASE measurements from a variety of conditions encountered during NASA hurricane field experiments over the Atlantic Ocean are presented. Comparisons of retrieved water vapor profiles from LASE near the surface with dropsonde measurements show very good agreement. This presentation also includes a discussion of the feasibility of developing space-based DIAL capability for high resolution water vapor measurements in the BL and above and an assessment of the technology needed for developing this capability.

9246-7, Session 2

A compact mobile ozone Lidar for atmospheric ozone and aerosol profiling

Russell J. De Young, NASA Langley Research Ctr. (United States); William Carrion, Coherent Applications, Inc. (United States); Denis Pliutau, Science Systems and Applications, Inc. (United States)

A compact mobile differential absorption lidar (DIAL) system has been developed at NASA Langley Research Center to provide ozone, aerosol and cloud atmospheric measurements in a mobile trailer for ground-based atmospheric ozone air quality campaigns. This lidar will be integrated into the Tropopheric Ozone Lidar Network (TOLNet) currently made up of four other ozone lidars across the country. The lidar system consists of a UV and green laser transmitter, a telescope and an optical signal receiver with associated Licel photon counting and analog channels. The laser transmitter consist of a Coherent Evolution 30 TEM00 1-kHz diode pumped Q-switched Nd:YLF inter-cavity doubled laser pumping a Ce:LiCAF tunable UV laser with all the associated power and lidar control support

units on a single system rack.

A custom-designed Ce:LiCAF tunable UV laser has a wavelength range of 282 to 300-nm that is selectable between two wavelengths. The current wavelengths are online 286 nm and offline 293 nm. The 527-nm visible beam is transmitted into the atmosphere for aerosol measurements. The fourth harmonic 262 nm beam is split by a beamsplitter into two pump beams that pump each face of the Ce:LiCAF crystal. A short laser cavity consisting of a 60% reflective (1m radius of curvature) output mirror, a dispersive prism and a flat HR mirror is used to produce the two UV wavelengths. In order to produce different wavelengths, the high-reflectivity rear mirror is mounted on a servo controlled galvanometer motor to allow rapid tuning between the on and offline ozone wavelengths. Typical laser results are 6.8-W at 527-nm, 800-mW at 262-nm and 130-mW at the UV transmitted wavelengths. The lidar receiver system consists of a receiver telescope with a 40-cm diameter parabolic mirror. A fiber optic cable transmits the received signal from the telescope to the receiver box, which houses the detectors.

To obtain an ozone atmospheric measurement, the transmitter sends a laser pulse into the atmosphere at alternating on-line and off-line wavelengths (500Hz each line). The 527-nm green laser output is transmitted at i-kHz. The system has been configured to enable mobile operation from a trailer and will be deployed to Denver, CO July 15-August 15, 2014 the DISCOVER-AQ campaign. Results of this campaign will be presented.

9246-8, Session 3

Advanced airborne Doppler Wind Lidar signal processing for observations in complex terrain *(Invited Paper)*

George D. Emmitt, Simpson Weather Associates, Inc. (United States); Kevin S. Godwin, KSG Science (United States); Steven Greco, Chris O'Handley, Simpson Weather Associates, Inc. (United States)

Over the past 13 years, an airborne Doppler Wind Lidar (ADWL) has been used in several field campaigns related to understanding and modeling lower tropospheric winds in complex terrain such as coastlines, ridge and valleys and isolated mountains. Making sense of lidar data in these regions presents several challenges in the areas of signal processing along single Line-of-sights (LOS) and the combining of multiple LOSs to compute 3D wind profiles. This presentation will discuss these challenges and provide illustrations using data from prior research projects.

The ADWL is a 2 micron coherent Doppler lidar flown on a Twin Otter operated by the Naval Postgraduate School in Monterey, CA. Frequently flown at an altitude of 3km, the TODWL (Twin Otter Doppler Wind Lidar) instrument is nadir conically scanned. Each scan takes ~ 20 – 25 seconds to complete during which time the aircraft moves ~ 1 – 1.5km. The more than 3000 laser "shots" are then combined to produce one or several vertical profiles of U, V and W with ~ 50m vertical resolution. Interpretation of these wind profiles derived from a cycloid pattern of samples must be done with care over flat terrain and even more so over complex terrain.

Over the years we have developed software that increases useful information extraction in very noisy and low SNR situations. This is especially the case within 150m of the surface where chirp in the lidar pulse and strong hard target returns from the ground combine to make it difficult to detect the air returns . A description of this problem and our success (limited) in getting to within 50 -100m will be provided.

An equally challenging situation is the combining of multiple LOSs taken from differing perspectives with differing intercepts of the surface to compute a 3D wind product. Using numerical weather models, mass continuity constraints and other techniques, new algorithms have been developed and are being tested against sparse but local in situ data.

One of our ultimate goals is to provide data sets that can be used to validate high resolution non-hydrostatic models and to provide guidance in developing better boundary layer parameterizations and subsequent mass and energy transport predictions.

9246-9, Session 3

2-micron Coherent Doppler Lidar instrument advancements for tropospheric wind measurement

Mulugeta Petros, Upendra N Singh, Jirong Yu, Michael J Kavaya, Grady J Koch, NASA Langley Research Ctr. (United States)

Knowledge derived from global tropospheric wind measurement is an important constituent of our overall understanding of climate behavior. Accurate weather prediction saves lives and protects properties from destructions. High-energy 2-micron laser is the instrument of choice for coherent Doppler wind detection. In addition to the eye-safety, the transmission wavelength of the transmitter suitably matches the aerosol size in the lower troposphere. Although the technology of the 2-micron laser has been maturing steadily, wind data is still a void in the global weather database. In the last decade, researchers at NASA Langley have been engaged in this endeavor, contributing to the scientific database of 2-micron lidar transmitters. As part of this effort, an in depth analysis of the physics involved in the workings of the Ho: Tm systems have been published. In the last few years, we have demonstrated lidar transmitter with over 1joule output energy. In addition, a large body of work has been done in characterizing new laser materials and unique crystal configurations to enhance the efficiency and output energy of the 2-micron laser systems. At present 2-micron lidar systems are measuring wind from both ground and airborne platforms. The presentation will provide an overview of the advancements made in recent years and the technology maturity levels attained.

9246-10, Session 4

A synopsis of CALIPSO polar stratospheric coud observations from 2006-2014 *(Invited Paper)*

Michael C. Pitts, NASA Langley Research Ctr. (United States); Lamont R Poole, Science Systems and Applications, Inc. (United States)

Polar stratospheric clouds (PSCs) are known to play key roles in the springtime chemical depletion of ozone at high latitudes. PSC particles (primarily supercooled ternary solution, or STS droplets) provide sites for heterogeneous chemical reactions that transform stable chlorine and bromine reservoir species into highly reactive ozone-destructive forms. Furthermore, large nitric acid trihydrate (NAT) PSC particles can irreversibly redistribute odd nitrogen through gravitational sedimentation (a process commonly known as denitrification), which prolongs the ozone depletion process by slowing the reformation of the stable chlorine reservoirs. Spaceborne observations from the CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) lidar on the CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) satellite are providing a rich new dataset for studying PSCs.

CALIOP began data collection in mid-June 2006 and has since acquired, on average, over 300,000 backscatter profiles daily at latitudes between 55 and 82 degrees in both hemispheres. PSCs are detected in the CALIOP backscatter profiles using a successive horizontal averaging scheme that enables detection of strongly scattering PSCs (e.g., ice) at the finest possible spatial resolution (5 km), while enhancing the detection of very tenuous PSCs (e.g., low number density NAT) at larger spatial scales (up to 135 km). CALIOP data are collected in three receiver channels - 532-nm parallel-polarized backscatter, 532-nm perpendicular-polarized backscatter, and 1064-nm

total backscatter, which together provide information on PSC particle shape and size, and hence composition. CALIOP PSCs are separated into composition classes (STS; liquid/NAT mixtures; and ice) based on the ensemble 532-nm scattering ratio (the ratio of total-to-molecular backscatter) and 532-nm particulate depolarization ratio (which is sensitive to the presence of non-spherical, i.e. NAT and ice particles). The composition classification scheme has been modified recently to account for denitrification, the primary effect of which is the misclassification of ice clouds as liquid/NAT mixtures.

In this paper, we will provide an overview of the CALIPSO mission and then examine the vertical and spatial distribution of PSCs in the Arctic and Antarctic on vortex-wide scales for entire PSC seasons over the more than eight-year data record.

9246-11, Session 4

High Spectral Resolution Lidar and MPLNET Micro Pulse Lidar aerosol optical property retrieval intercomparison during the 2012 7-SEAS field campaign at Singapore

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From August 2012 to February 2013 a High Resolution Spectral Lidar (HSRL; 532 nm) was deployed at that National University of Singapore near a permanent NASA Micro Pulse Lidar NETwork (MPLNET; 527 nm) site. A primary objective of the MPLNET lidar project is to provide reliable Level 1 measurements and Level 2 retrievals. This paper examines and quantifies error in retrieving Level 2 aerosol optical properties through inversion techniques that derive backscattering and extinction coefficients from MPLNET elastic single-wavelength datasets. MPLNET Level 2 retrievals for aerosol optical depth and extinction/backscatter coefficient profiles are compared with corresponding HSRL datasets, for which the instrument collects direct measurements of each using a unique optical configuration that segregates aerosol and cloud backscattered signal from molecular signal. The intercomparison is performed, and error matrices reported, for lower (0-5km) and the upper (>5km) troposphere, respectively, which distinguishes uncertainties observed within and above the MPLNET instrument optical overlap regime.

9246-12, Session 4

Comparison between Haar and Mexican Hat function to obtain the height of atmospheric boundary layer

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LIDAR systems have been appointed by many authors as one of the best tools to obtain atmospheric information, allowing to provide good monitoring of PBL (Planetary Boundary Layer), since it can afford near-real time data with high spatial and temporal resolution. Moreover, this kind of system enables the retrieval of data without the influence in the study object.

In order to improve the analysis and determine confident values of PBL height during their diurnal variation it is necessary to employ mathematic algorithms. In this sense, one of the most used is the WCT (Wavelet Covariance Transform) method, applied to detect changes in signals that contain sharp transitions.

The WCT consists in making the covariance between RCS (Range Corrected Signal) and mother wavelet function, being that the most used function is the Haar, because ithas a similar profile at lidar signa,. although, others wavelets functions can be applied as well.

The main objective of this work is to compare two mother wavelet functions (namely Haar and Mexican Hat functions) applied to the detection of PBL height, and to verify advantages and disadvantages of each one underdifferent scenarios, , with meterological condition favoring a stable PBL and those which somehow provide less conditions for stability. The validation was performed by modeling from HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory Model) and radiosounding data from Richardson Number.

For this study two campaigns were conducted in the Metropolitan Area of São Paulo (MASP) – São Paulo State - Brazil in two different seasons (Winter and Summer) in order to observe how specifics characteristics of each season can influence the WCT algorithms. A case study of each season will be presented, where were employed a LIDAR system operating with wavelength of 532 nm to retrieve the vertical profiles of aerosol distribution.

From the results of this work it was possible to better understand how each function behaves and their particularities. It was also possible to observe the better way to choose the dilation length and the center of the function (a and b parameters respectively), which are the the most difficult and also the most important issues when applying the wavelet functions,in general an iterative process was applied until a height and layer size were found.

9246-13, Session 4

New Lidar facility at Lindenberg Meteorological Observatory, Germany

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Since 2005, the high-performance multiparameter Raman lidar RAMSES (Raman lidar for atmospheric moisture sensing) for water-vapor, temperature, cloud and aerosol measurements is part of the broad suite of active and passive remote-sensing instruments monitoring the atmosphere at the German Meteorological Service's observatory in Lindenberg. Initially housed in a 20-foot container, continued expansion of RAMSES made accommodation of the instrument increasingly difficult, and caused problems in air-conditioning. For these reasons, a new lidar facility was built on site in 2013. It is now home to RAMSES, and it also provides extra laboratory space for (lidar) experiments.

The Lindenberg lidar facility is described in detail. One of its features is the precision air-conditioning system which is designed to keep the temperature field of the RAMSES room stable within 1 K at all times. Migration from the container to the new building offered an opportunity to make changes to the RAMSES instrument itself. For instance, stray light suppression was further improved, selection of photomultiplier tubes was optimized, and the near-range receiver was redesigned to enhance its daytime capabilities. Further, in addition to the water spectrometer for calibrated measurements of cloud Raman backscatter-coefficient spectra, a second spectrometer was implemented for studies of the fluorescence spectra of atmospheric aerosols. At the conference, these technical modifications are discussed,

and first measurement examples with the improved lidar are presented.

9246-14, Session 4

LED mini-lidar as minimum setup

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The LED mini-lidar has been designed and demonstrated as the near range atmosphere monitoring and dust detection. The LED lamp is used as a lidar light source. It is not a special one, and just used as a small status indicator or a spot luminaire. For the atmospheric monitoring in the near range of a few hundreds meters, the energy of 1nJ (=100mW/10ns) is enough for lidar observation in the nighttime. The LED lamp is excited at the high repetition frequency of < 1MHz. The signal-to-noise ratio can be increased by this high frequency even if the receiving photons are a little at each pulse. It is adequate because the spatiotemporal scale of the low-altitude atmosphere is small of a ten seconds and a few tens meters. To pursue the quick motion of the atmosphere and dust, the high-speed photon counter has been developed. It can act with BIN width of 4ns (Spatial resolution 0.6m) at the repetition frequency of >500kHz. Now, its performance is improved with BIN width of 1ns (Resolution 0.15m) at the same high frequency. Although the LED beam is not easy to collimate, especially in high efficiency, conversely it becomes easy to make alignment between the transmitting beam and receiver's filed of view. The spreading beam leads robust the lidar alignment. It is essential at the on-site observation.

The LED mini-lidar has been demonstrated to monitor the actual atmosphere of the observation range of >500m in the nighttime and 150m in the daytime with the receiving lens of 200mm?. The small setup with the receiving telescope of 100mm? and the transmitting LED beam of 30mW could detect the low-altitude atmosphere of <100m and dust. The interest approach is tired to distinguish the dust characteristics by using the counting rate of dust echoes. It is effective in the case that the dust material is given.

To adapt the LED mini-lidar on-site, it is optimum to use it on a small vehicle such as MAV (Micro Air Vehicle), rover and robot for disaster relief. The LED lamp is small, robust, no-use to cooling, and cheap. The optical system can be thrown into the observation point and obtained data can be stored though wireless interface. Now the several designs for the Mars rover and MAV are making progress. In the case of the Mars rover, the observation of Mars dust devil is the main target, and the installation on MAV is for the approach to the restricted area such as the disaster site.

9246-15, Session 4

Evaluation of the hygroscopic behavior of aerosols over Sao Paulo: one-day case study

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The determination of the water vapor content in the atmosphere using LIDAR systems is being demonstrated to be very useful, as LIDARs can operate continuously. The Raman LIDAR has the ability of determining the water vapor mixing ratio (WVMR) using the ratio between the signal backscattered by water molecules and nitrogen molecules in the atmosphere, and this information can be used to derive the relative humidity (RH) profile using temperature from other co-located instruments or models. In conditions in which a large increase of the RH in a well-mixed atmosphere is verified, the changes in aerosol properties are due to the water uptake and the hygroscopic behavior of the aerosol population can be derived. The Raman LIDAR presents many advantages in this study, because the laser can operate in conditions of relative humidity next to saturation and under unperturbed atmosphere conditions.

In São Paulo, the IPEN LIDAR Group is running a Raman LIDAR with three channels since January 2012: 355 nm and the corresponding Raman wavelengths 387nm (nitrogen) and 408nm (water vapour), providing information of the water vapor mixing ratio. The values obtained are calibrated using independent calibration, such as a lamp and co-located radiosoundings.

In this work, we present a case study of determination of the hygroscopic growth factor (f(RH)) of aerosols over São Paulo in September 2012, using a well-known methodology from literature. The Lidar was used to derive the RH and the result were compared with the radiosounding, showing good agreement. The f(RH) also showed good agreement with data found in literature for the same type of aerosol. We include a discussion of the limitations and future applications of this methodology.

9246-16, Session 4

Lidar measurements of tropospheric aerosol and water vapour profiles during the winter season campaigns over the metropolitan area of São Paulo, Brazil

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High populated regions suffer constantly with elevated concentration of aerosol, which can affect not only the climate but also impair the air quality, bringing several issues to the health of population. The so-called Metropolitan Area of São Paulo (MASP), one of the largest megacities in the world, faces several problems related to the air quality due the high concentrations of aerosols produced either by local sources or by long-range transportations. Concerned with the elevated concentrations of aerosol and their impact in the air quality and the climate changes inside MASP, two measurement campaigns were conducted during the south hemisphere winter season of 2012 and 2013 using a six-channel Raman Lidar system and air quality monitoring stations from University of São Paulo and Environment Agency of São Paulo State (CETESB). Using the Raman Lidar system it is possible to retrieve aerosol optical properties in the vertical coordinate such as backscatter, extinction, lidar ratio and also water vapour mixing ratio distribution, and from air quality monitoring station one can retrieve particulate matter concentration in near-ground level.

Meteorological data from a local weather station shows that 2012 winter was drier than 2011 and 2013 winters. During this period MASP experienced episodes of high air pollution concentration, reaching AOD values of 0.80 to 1.0 at 550 nm and particulate matter concentration of 210 ug/cm3, for relative humidity values of 23%. As part of NUANCE-SPS (Narrowing the Uncertainties on Aerosol and Climate Changes in São Paulo State) project, this study intends to explore aerosol optical properties, their vertical distribution, particulate matter concentration and water vapor mixing ratio information during these two seasons with different meteorological scenarios.

9246-17, Session 4

MPLNET lidar data assimilation in the ECMWF MACC-II Aerosol system: evaluation of model performances at NCU lidar station

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Atmospheric profiles of the optical aerosol properties through the retrieved backscattering or extinction coefficients by lidar measurements can improve drastically the MACC-II aerosol model performances on vertical dimension. Currently the MODIS Aerosol Optical Depth data (both from Terra and Aqua) are assimilated into the model. Being a column-integrated quantity, these data do not modify the model aerosol vertical profile, especially if the aerosols are not interactive with the meteorology. Since 1999, the MPLNET lidar network provides continuously lidar data measurements from worldwide permanent stations (currently 21), deployed from the Arctic to the Antarctic regions and in tropical and equatorial zones. The purpose of this study is to show the first preliminary results of integration of MPLNET lidar data profiles into MACC-II model for some selected test measurement sites. This is the first step to assimilate lidar measurements into MACC-II aerosol model forecast in near-real time.

9246-20, Session PS

Error propagation of exterior orientation elements study on space-borne laser altimeter ground positioning

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As a way of acquiring elevation with high accuracy, space-borne laser altimeter improves the capability of 3-dimensional cartography of satellite optical remote sensing imagery. However, the plan accuracy of space-borne laser altimeter is not so high as its elevation accuracy. Because of high orbit and low frequency pulse, space-borne laser altimeter usually has big laser footprints and ground sampling distance, which is very different from the dense point cloud data of air-borne laser altimeter. The processing of space-borne laser altimeter data is also quite different from that of air-borne laser altimeter data. Space-borne laser altimeter laser echo signal describes whole distance information of the big laser footprint, and the elevation is obtained from the laser echo signal by som algorithm. In order to make good use of the space-borne laser altimeter data for earth observation, the error souses and their influences on space-borne laser altimeter ground positioning are studied in this paper.

Space-borne laser altimeter is very different from classical photogrammetry, the elevation information is obtained by measuring the time between sending and receiving laser. As space-borne laser altimeter supplies laser echo signal other than image, there are no photogrammetry interior orientation elements in space-borne laser altimeter, and the exterior orientation elements errors are main error souses in space-borne laser altimeter ground positioning.

In this paper, the geo-positioning function of space-borne laser altimeter is first modeled. The same as collinear equation, space-borne laser altimeter projection center and observation ground point are in a same space line. Space coordinates of observation ground point are obtained according to the space-borne laser altimeter pointing direction and the distance between space-borne laser altimeter projection center and observation ground point. The space-borne laser altimeter geo-positioning model is analysed to find out the error souses of space-borne laser altimeter ground positioning. Then error propagation os the error souses in the model is studied. We decompose the error souses, and the error souses for each space coordinate error of observation ground point are distinguished. Due to the error souses decomposition, we can get the answer which are the error souses for the observation ground point space coordinate X, which are the error souses for the observation ground point space coordinate Y, and which are the error souses for the observation ground point space coordinate Z. Further more, in order to get the knowledge how much the error souses impacted the space-borne laser altimeter geo-positioning accuracy, we do some experiments of the main error souses influences on space-borne laser altimeter designing and application.

9246-21, Session PS

Synergy between ground-based remote sensing systems in microphysical analysis of cirrus clouds

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At the Meteorological Observatory Lindenberg, Germany, a broad suite of ground-based remote sensing instruments are measuring atmospheric profiles of hydro- and thermodynamic variables as well as cloud optical and microphysical properties.

For the first time, the data of a Raman-LIDAR, a Ka-band cloud radar, a 5° tilted ceilometer, a 482MHz radar wind profiler and a 1.5 ?m Doppler lidar are used to synergistically analyze cirrus cloud microphysics.

The key instrument is the high-performance, multiparameter Raman-LIDAR for atmospheric moisture sensing (RAMSES) for autonomous and continuous measurement of water vapor, temperature, aerosol and clouds. 85 days of cirrus cloud measurements have been selected from the RAMSES archive to analyze the correlation between, and the dependences of, the different measured variables. The presented study investigates the effect of the spatial orientation and the shape of solid cloud particles on the particle optical properties and their relation to wind and turbulence parameters. A statistical overview is given and case studies are discussed.

A sensitive indicator of particle spatial orientation is the particle depolarization ratio (PDR).

When ice crystals are horizontally aligned, mirror reflections can occur which is evidenced by low PDR (and a large backscatter ratio) if observed with a vertically pointing lidar such as RAMSES. In contrast, the tilted ceilometer is not affected by mirror reflections and can thus be used to identify and further characterize cirrus layers with oriented particles in the RAMSES data.

The data set is split into cirrus cases observed during passing frontal systems (29 days, set 1) and under other weather conditions (56 days, set 2). It is found that there are days with a vertically and temporally constant PDR for long time periods. Half of the measurement cases of set 2 show cirrus with exclusively small PDR (13 out of 56 days) or only large PDR (10 days). In frontal liftings (set 1) there are just eight days out of 29 days with a stable PDR.

Interestingly, during warm fronts the PDR is small (<0.2), and during cold fronts it is high (>0.4). In all other measurement cases of set 1 and 2, PDR exhibits strong temporal and spatial variability.

Moreover, the mean lidar ratio of cirrus with high PDR is about 20 sr, two times larger than of cirrus with low PDR. Similar dependences on PDR have been found for the particle extinction coefficient (0.2 vs. 0.1 km-1) and the backscatter coefficient from the tilted ceilometer (0.0045 vs. 0.0016 km-1sr-1). But for the RAMSES backscatter coefficient in

perpendicular polarization the opposite behavior is observed, the average value is only about half in cirrus with high PDR as compared to those in ice clouds with low PDR (0.01 vs. 0.02 mm-1). Finally, no statistically significant correlation has been found between the terminal velocity and the other parameters such as PDR so far.

9246-22, Session PS

Use of Lidar technology in forest fuel structure measurements for development of dynamic fuel hazard models

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Fuel characteristics, such as chemical composition and physical structure, as well as fire weather and topography, have significant influence on fire development and propagation. The development of accurate and reliable methods to quantify forest fuel characteristics and to understand forest fuel dynamics is an ongoing requirement of government, fire authorities and land management agencies, due to the continual need for improvement in fire resource management, bushfire suppression, and in framing bushfire related policies.

Fuel characteristics can be described in numerical terms by fuel loading, fuel depth, and fuel particle density. Over the last four decades, the definition of fuel characteristics in Australia has changed from fuel load to fuel structure, along with the development and modification of fire danger and behavior models. Fuel load is defined as the surface fuel or fine fuel loading (fine leaf and twig material that are less than 6 mm in diameter), and quantified as tonnes per hectare; fuel structure relates to three-dimensional fuel arrangement within a vegetation profile. Traditionally, wildland fuel measurements are based on field survey sampling in order to directly measure fuel characteristics, which is time and labour intensive. Moreover, this method is too slow for predicting ongoing bushfire behavior, when large areas are involved.

Light Detection and Ranging (LiDAR) technology potentially provides a fast and cost-effective method for measuring fuel characteristics. Airborne LiDAR provides continuous, high accuracy digital elevation and surface data on a landscape scale. It has been successfully applied in estimating forest inventory and biomass, mapping forest structures, and measuring individual trees. In terms of fuel measurements, airborne LiDAR implements a three dimensional survey based on multiple pulse returns, and the backscatter signal is a function of forest fuel structures. However, it has a limitation in capturing forest surface fuel when fewer pulses reach the ground in very dense forests. The surface fine fuel load affects fire behavioral characteristics such as ignition and rates of fire spread, both of which are key inputs into fire danger and behavior models.

In this study, a terrestrial LiDAR survey is being undertaken to address this problem. Terrestrial LiDAR systems produce point clouds of higher density and higher laser ranging accuracy than the airborne systems, and can scan a full hemisphere from a point on the canopy floor to tree stem and foliage densities. Forest fuel structure measurements based on an integration of airborne and terrestrial LiDAR technologies at a larger scale can be time effective, cheap and objective. This study aims to review LiDAR application in mapping forest structures and evaluate the potential use of emerging airborne and terrestrial LiDAR surveys in forest fuel structures on a landscape scale. Such an integrated approach can be used for a future study to develop fuel hazard dynamic models for better prediction of fuel hazard, and also to assist fire agencies and land managers in developing more realistic fire involved policy (e.g. fire risk management and bushfire safety policy) and planning strategies (e.g. forest fuel reduction burning).

9246-23, Session PS

Characterization of smoke particle properties from multiwavelength Raman lidar measurements

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Multiwavelength Raman lidars nowadays are widely used for characterizing particle intensive properties such as extinction (??) and backscattering (??) Ångström exponents together with lidar ratios, which are important parameters for aerosol classification. However lidar exploiting nitrogen vibrational Raman scattering monitors backscatter at 387 and 608 nm from 355 and 532 nm laser wavelengths, correspondingly, so assumptions about the value of the Ångström exponent are needed for calculations of backscattering and extinction coefficients. Normally only ?? at 355-532 nm wavelengths is available from the measurements, thus unknown ?? at other wavelengths may be additional source of the errors. This is especially important for the particle size distributions (PSD) with predominant fine mode, which are characterized by a strong spectral dependence of the Ångström exponent. In our presentation we provide numerical simulation of uncertainties arising from an unknown value of ?? for different wavelengths, and PSDs. One of the goals of the simulation performed here was to establish the correlation between backscattering Ångström exponent ??(355-532), ??(532-1064) and extinction Ångström exponent ??(355-532). The dependence ??(??) for different wavelength pairs is quite sensitive to the particle size and refractive index. We will demonstrate that corresponding plots can be used for a preliminary analysis of the particle parameters.

Simulation results are compared with experimental measurements performed at NASA GSFC in Greenbelt, MD in August 2013. Smoke from forest fires was transported from the West coast of the United States and several strong intrusion episodes were detected with multiwavelength Raman lidar over Washington DC area along the east cost of the US. The aerosol layers extended up to 4 km in height so a strong height dependence of the retrieved particle parameters was observed. Thus particle effective radius was higher in the PBL and decreased in the smoke layer, while the real part of the refractive index increased with height up to 1.6 in the smoke layer. The uncertainties of retrieved parameters due to the choice of the Ångström exponent were analyzed.

When inverting lidar measured extinction and backscattering to aerosol microphysical properties, the particles are normally assumed to be uniform spheres. However particles may contain an external coating or shield. To analyze the possible effect of such a shield on the retrieval we performed the numerical simulation, assuming that all the particles in the distribution are covered by the shield of the same thickness. Results of computations performed for different PSDs, shield thickness and refractive indices will be presented.

9246-24, Session PS

Instrumental correction of the uneven PMT aging effect on the calibration constant of a water vapor Raman Lidar

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The water vapor profile derived from Raman lidar measurements is obtained by taking the ratio of water vapor

and nitrogen Raman-shifted signals. The proportionality factor that converts the signal ratio to water vapor/air mixing ratio is referred to as lidar calibration constant. The calibration constant depends on the receiver efficiency, including the photomultiplier (PMT) efficiency.

In general the nitrogen signal is stronger because of the higher nitrogen concentration and to avoid nonlinearities we attenuate the nitrogen signal ten times by a ND filter. The ND filter, however, causes different background light exposure during day time measurements, which results in faster aging of the water vapor PMT and a decrease of the lidar calibration constant.

The differential aging effect has been observed during the seven- year continuous operation of the Raman Lidar for Meteorological Observations (RALMO) (Dinoev, AMT, 2013). A more detailed research (Brocard, AMT, 2013) has shown that the calibration constant decrease is more pronounced during the summer time due to the higher light exposure. Periodical recalibration of the lidar with radiosonde measurements is used to correct the calibration constant. This approach, however, induces additional systematic errors due to the nature of the calibration procedure and the dispersion of the radiosonde parameters.

We present a new automated instrumental method for correction of the uneven PMT aging effect on the calibration constant of a water vapor Raman lidar. With this method, a correction factor is deduced from the ratio of the signals of the two photomultipliers which are illuminated simultaneously by a single, stabilized UV LED light source. The LED light is delivered to the photomultipliers by a set of additional mirrors and a beam splitter installed inside the grating polychromator to separate the Raman signals. The correction measurements are taken for 10 min before midnight. To avoid additional data loss the lidar's laser is operated during the measurements and a shatter at the polychromator entrance is used to block any atmospheric signals. An additional stable light source allows the measurement of the individual photomultipliers aging rates, essential for the instrument maintenance.

We shall discuss the practical design of the calibration correction system, show its implementation in the RALMO lidar system and finally discuss the measurements of the PMT aging and their effect on the system's calibration.

9246-25, Session PS

Towards an instrumental harmonization in the framework of LALINET: dataset of technical specifications

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LALINET (http://lalinet.org) is a Latin American coordinated lidar network focused on the vertically-resolved monitoring of the particle optical properties distribution (i.e. particle backscatter and extinction profiles) over Latin America, as well as other atmospheric species such as ozone and water vapor. On voluntary basis, this federative lidar network, started in 2001, aims to establish a consistent and statistically relevant database to enhance the understanding of the particle distribution over the continent and its direct and indirect influence on climate. However, the creation of an un-biased spatiotemporal database requires a throughout review of the network on two pillars: instrumentation and data processing. Regarding instrumental aspects, two networking activities have been recently launched, namely (i) collection of information to generate a dataset of technical specifications, and (ii) application of quality tests to improve the characterization of LALINET systems. In this study we present results concerning the first task.

At present, this lidar network consists of 11 lidars operated by 7 groups in 9 stations distributed over South America, covering from Cuba to Argentina and from Chile to Brazil. Most of them are not series-produced instruments and, therefore, present large differences in configuration and capabilities. Thus, the performance of each non-standardized instrument may be different and attempts for network harmonization and, consequently, optimization is mandatory. To this aim, an instrumental inventory was distributed, structured to accommodate a wide variety of lidar configurations. The information to be fulfilled for each instrument, with around 80 different entries, is organized as follows:

-section 1: station information

-section 2: mode of operation

-section 3: emitter

-section 4: receiver optics

-section 5: wavelength detection

-section 6: data acquisition

-section 7: auxiliary information

The compiled information will be stored in an incremental database representing the network metadata repository. It is envisaged that the database will be updated every time that one of the parameters recorded will change at one of the instrument. It will allow us to have the updated instrumental information from the whole network and at the same to keep tracking of all the changes occurring in time.

By means of this networking task, which must not be underestimated due the huge number of instrumental characteristics considered, is expected not only to provide an exhaustive overview of the individual LALINET systems but also to find common instrumental solutions to state-of-the-art common problems. This will bring benefits to both the existing stations and to the new groups, and will help the improvement of the over-all quality of the aerosol data products derived from LALINET for contributing to the scientific knowledge.

9246-26, Session PS

Application of the adaptive segmentation smoothing method in the atmospheric detection by a space-based Lidar

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The atmospheric detection signal of the space-based lidar always suffers from the noise of the background light, shot noise, dark current, thermal noise, etc. Because of the noise mentioned above, the signal fluctuates significantly around the true value, and the fluctuation will result in errors in the inversion processing. An adaptive segmentation smoothing method (ASSM) is introduced in the paper to smooth the signal and suppress the noise. In the ASSM, the noise is defined as the 3? of the background signal. An integer number N is defined for finding the changing positions in the signal curve. If the difference of adjacent two points is greater than 3N?, the position is recorded as an end point of the smoothing segment. All the end points detected as above are recorded and the curves between them will be smoothed separately. In the traditional method, the end points of the smoothing windows in the signals are fixed. For example, the end points could be set as 0~3km, 3~6km and >6km, in the signal of a ground-based lidar, and the end points will not change even if the signals changes dramatically (e.g. signals with cloud or without cloud). And the smoothing windows could be 0.3km, 1km and 2km in the segmentations separately. If the signal is obtained in a cloudy day and the cloud base is around 4km, the smoothing result will be aberrant dramatically. Being different from the traditional method, the ASSM creates changing end points in different signals and the smoothing windows could be set adaptively. The windows are always set as the half of the segmentations and then the average smoothing method will be applied in the segmentations. The Iterative process is required for reducing the end-point aberration effect in the average smoothing method and two or three times are enough. In ASSM, the signals are smoothed in the spacial area nor frequent area, that means the frequent disturbance will be avoided in the method. The frequent disturbances always appear in the frequent filtering method like wavelet, Fourier, etc. A lidar echo was simulated in the experimental work. The echo was supposed to be created by a space-born lidar (e.g. CALIOP). And white Gaussian noise was added to the echo to act as the random noise resulted from environment and the detector. The novel method, ASSM, was applied to the noisy echo to filter the noise. In the test, N was set to 3 and the Iteration time is two. The results show that, the signal could be smoothed adaptively by the ASSM, but the N and the Iteration time might be optimized when the ASSM is applied in a different lidar.

9246-27, Session PS

Tropospheric Raman Lidar measurements of the vertical aerosol backscattering with range-dependent Lidar ratio in Penang Island, Malaysia, during the dry season

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In Malaysia, there are usually two distinct dry seasons: from January to March, and from June to September. During these periods of the year, the weather is very hot and dry and both anthropogenic and natural forest fires happen, injecting a large quantity of smoke in the atmosphere that is affecting the air-quality.

Since March 2014, at School of Physics, Universiti Sains Malaysia (5.36°N, 100.30°E), a 355nm backscatter Raman Lidar operates at regular time intervals. Studies on retrieved aerosol vertical profiles help to assess and discriminate between aerosol local sources and transport over Penang Island, during the dry season in Malaysia. The Raman technique permits to retrieve the aerosol lidar ratio independently. The Lidar ratio then can be used to discriminate the different aerosol species. The results of the lidar ratio confirm that local marine environment was present with biomass burning smoke intrusions in certain cases. It was also found that aerosol is mostly confined in the first 3km of the atmosphere. HYSPLIT back trajectories help to determine the air-mass origin and then the possible source of the transported aerosol. The results can provide important information on regional aerosol transportation around Southeast Asia. These first raman lidar measurement results is essential to setup Penang Island as a fixed observational site to monitor regional aerosol transportation and provide useful information in the study of regional aerosol climatology.

9246-28, Session PS

Fiber optic humidity sensor based on Fabry-Perot interferometer

Zhi Zhuang, Yi Zhang, Yongjian Mao, China Academy of Engineering Physics (China); MingHong Yang, Wuhan Univ. of Technology (China) and Key Lab. of Fiber Optic Sensing Technology and Information Processing, Ministry of Education (China)

A new type of fiber optic humidity sensor based on Fabry-Perot interferometer (FPI) is designed, which is formed by dielectric thin films. The structure of sensor and sensing principle as well measurement system are introduced briefly in this paper.

Three layers of Ti3O5/SiO2/Ti3O5 thin films are deposited on the fiber end using e-beam evaporation techniques. The thicknesses of high refractive index (RI) Ti3O5 thin film and low RI multi-hole SiO2 thin film are 168 nm and 1621 nm, respectively. The three thin films form a Fabry-Perot cavity as the humidity sensing element. When the relative humidity (RH) of the environment changes, the RI of the SiO2 thin film will change accordingly, and finally causes the shift of the reflected peak wavelength of the F-P cavity. If the relation of the RH and wavelength variation is calibrated, the RH measurement can be realized by measuring the variation of the spectrum.

In calibration experiment, the light emitted from a tungsten lamp reaches the humidity sensing probe through one branch of a multimode fiber coupler, and the reflected light by the sensing probe is received by a miniature optical spectrum analyzer (OSA) through another branch of the coupler which is finally sent into the software for data analysis. A high precision dew-point hygrometer and a dynamic humidity generator is used to provide a wide range humidity environment of 0% RH~100% RH and realize a wide range static calibration for the proposed fiber optic humidity sensor.

It can be concluded from the experimental results that the Ti3O5/SiO2/Ti3O5 thin film is suitable for medium RH range (0% RH ~70% RH). The sensor is with high sensitivity and linearity in the range of 0% RH~40% RH and its wavelength variation grows slowly in the range of 40% RH~70% RH. When the RH is higher than 70% RH, its wavelength keeps almost unchanged.

By analyzing the experimental data, we can also obtain the measurement accuracy, the sensitivity and the response time of the sensor, which are 2.8%FS, 0.4 nm/%RH and 1 s~3 s ,respectively.

9246-29, Session PS

An inspection approach for airborne Lidar data filtering and qualification

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Airborne LIDAR captures the high-resolution 3D spatial coordinates of the earth's surface and coverings and forms point cloud data in a very short period of time by illuminating targets with a laser and analyzing reflected and multiple echoes. By filtering the point cloud data, surface coverings such as buildings, bridges and vegetation can then be classified as non-ground points while appropriate points in the point cloud can be interpreted as ground points, thereby generating digital surface models (DSM) and digital elevation models (DEM). In current practices, two-stage validation that includes point cloud and DEM is the most common. Point cloud validation interprets terrains mainly based on collective data from point cloud, aerial photos, and rough terrain models to determine the accuracy of point cloud classification. However, point cloud validation tends to be subjective because results often vary when different people conduct point cloud validation on the same area. DEM validation interprets using DEM mainly based on terrain categories, coverage of the earth's ground by vegetation, i.e. the average elevation of vegetation coverage on the surface, and there are already quantification standards for such interpretation. Results of ground point classification are directly linked to the quality of DEM products. According to current specifications, point cloud density for different slopes can reach 1.5 to 2 points per square meter, so final DEM products remain fairly accurate even if ground point classification has slight gaps. In view of the foregoing, the intent of this study is to establish a quality assessment process that estimates the reasonable classification accuracy in accordance with current DEM specifications, based on which considerable classification achievements can be expected. Based on this quality assessment process, our experiment consists of internal quality assessment, by which empirical accuracy is obtained, and external assessment of relative errors, which uses reference values to verify the rationality of the empirical accuracy.

9246-30, Session PS

A multiwavelength Lidar system based on an erbium-doped fiber MOPA-system

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A multi-wavelength fiber based MOPA-system is proposed for application in a coherent Doppler lidar system to increase the sensitivity of fiber based single-wavelength lidar systems. The system shown in Fig. 1 consists of a master oscillator setup of four ECL-diodes tuned to ITU-grid wavelengths close to 1550 nm which is principally scalable. Bandwidths and stability of these laser modules are less than 100 kHz which allows long range coherent detection. The channels are chosen for best transmission in the atmosphere and highest gain concerning the EDFA gain response. The multiplexed output of the four lasers is guided (1) to the detector unit, where it is demultiplexed to serve as four local oscillators (LO) for each wavelength and (2) to the pulse-shaping unit. In this unit the demultiplexed cw-wavelengths are individually modulated by electro-optical modulators (EOM) and after this the multiplexed pulses are frequency shifted by 110 MHz with an acousto-optical modulator (AOM). The pulses seed a standard two stage erbium-doped fiber amplifier. Amplifier fibers and all connecting fibers as well are polarization maintaining.

The transmitted and received beams are separated by a circulator, whereas the p-polarized transmitted light laser is converted into circular polarized light by a quarter-wave plate. The received lidar signal is guided through a polarizing beam-splitter (PBS) to increase the isolation of the circulator and then demultiplexed. Each wavelength of the lidar signal is mixed with the corresponding LO on a balanced detector. Electrical outputs are filtered by bandpasses, amplified and digitized by four ADCs with 1GS/s each wavelength channel.

Usually there are two possibilities to improve the figure of merit of lidar systems: increase of pulse energy and pulse repetition frequency (PRF). Stimulated Brillouin scattering (SBS) limits the output power of erbium-doped fiber amplifiers when spectrally narrow pulses are demanded. Different attempts to overcome this limitation are discussed in literature for example LMA-amplifier fibers, photonic crystal fibers , dispersion variation along the fiber amplifier induced by stress or temperature gradients. The PRF is limited in the case of longer ranges due to second trip interference. As mode competition between multiple wavelengths can be neglected due to the large separation of channels the multi-wavelength attempt shows improvements of performance using commercial fiberoptical components.

Measurements were performed using hard target reflection and atmospheric scattering to demonstrate the improved sensitivity of fiber based multi-wavelength lidars. First, the SBS threshold for each wavelength in the EDFA is mostly independent, which benefits the total output power. Second, a higher PRF is possible for long ranges due to the parallel processing. Third, the separation of the channels is high enough, leading to a diverse realization of the speckle field for each channel which provides an increased rate of evaluable rangegate signals. Fourth, accumulated backscattered signals from different channels show higher sensitivity due to the existence of correlations between simultaneously registered signals from different channels .

With these methods an overall increase in SNR of conventional fiber based lidars can be achieved.

9246-31, Session PS

Development of a laser for differential absorption Lidar measurement of atmospheric carbon dioxide

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We report the design, development and first tests of a laser source for the measurement of atmospheric carbon dioxide (CO2) by the differential absorption lidar (DIAL) technique. DIAL requires a laser which can provide two defined wavelengths: an on-line wavelength precisely tuned to a specific absorption line of CO2, and an off-line wavelength tuned slightly away from the absorption line. The laser must be able to rapidly switch between on-line and off-line wavelengths, its spectral width must be narrow relative to the CO2 absorption line width, and it must be pulsed to provide spatially-resolved measurements.

These requirements have been met by designing and building an optical parametric oscillator (OPO) pumped by a pulsed neodymium-doped yttrium lithium fluoride (Nd:YLF) laser. The OPO can produce output wavelengths close to CO2 absorption lines near 1.6 μm, enabling the use of technologies designed for telecommunications. Precise wavelength control is achieved by seeding the OPO with a pair of distributed feedback laser diodes, one at the on-line wavelength, the other at the off-line. The on-line wavelength is stabilized by locking it to the selected absorption line of CO2 measured with a multipass gas cell. An optical fibre switch can rapidly toggle between the two wavelengths.

The design of the laser source is described and the results of initial tests reported. The laser is suitable for a CO2 DIAL instrument with a maximum range of several kilometres.

9246-32, Session PS

Development of PM2.5 density distribution visualization system using ground-level sensor network and Mie lidar

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1. Background and purpose

Atmospheric particulate matters (PM) are tiny pieces of solid or liquid matter associated with the Earth's atmosphere. They are suspended in the atmosphere as atmospheric aerosol. Recently, density of fine particles PM2.5, diameter of 2.5 micrometers or less, from China is serious environmental issue in East part of Asia.

In this study, we develop a PM2.5 density distribution visualization system using ground-level sensor network and Mie lidar. The former dataset is used for visualization of horizontal PM2.5 density distribution and movement analysis, the latter dataset is used for visualization of vertical PM2.5 density distribution and movement analysis, Skyradiometer dataset is also used for identify aerosol size parameter.

2. Sensors and Equipment

(1) Ground-level PM2.5 observation station

We use ground-level sensor network dataset for horizontal PM2.5 density distribution and movement analysis. Ground-level air pollutant data including NOx, Sox, oxidant and PM2.5 are acquired by local air pollutant observation station in Japan every hour. These data are distributed at Atmospheric Environmental Regional Observation System (AEROS) web sitecite{SORAMAME} in HTML language. In Kyushu, 99 PM2.5 observation stations are distributed.

(2) Mie lidar

We use Mie lidar dataset and Skyradiometer dataset for vertical PM2.5 density distribution and movement analysis. A compact multi-wavelength aerosol Mie lidar installed at Saga University were two-wavelength polarization lidar systems, the fundamental and second harmonic having wavelengths of 1064 [nm] (?1) and 532 [nm] (?2), respectively. In addition, this lidar has 607 [nm] channel which can observe Raman shifted backscatter signal of???2 by nitrogen molecules in atmosphere. Backscattered photons from the atmosphere are collected by one Ritchey-Chretien type telescopes. A polarizer divided photons at ?2 into components parallel (P) and perpendicular (S) to the transmitted laser polarization plane.

The received photons were converted to electrical signals by an avalanche photodiode (APD) at ?1, ?2 and its Raman shifted wavelength, four photomultiplier tubes (PMT) were used to simultaneously obtain high-dynamic-range signals from near the surface to an altitude of 40 km. Transient recorders used a 12-bit analog-to-digital (A/D) converter and a photon counter to process the output signals of the APD and PMTs. Because the APD signals were noisy above altitudes of about 20 to 25 km, we used only lidar data at $lambda_2$ for stratospheric aerosols.

3. PM2.5 visualization system

We develop a PM2.5 visualization system to analysis horizontal PM2.5 density distribution and movement. This system is a HTML5 web-base system. The system can demonstrate color latest PM2.5 distribution image and movie of recent 10 days. This system also can demonstrate gray scale latest PM2.5 distribution image and movie of recent 10 days for users with specific color perception.

4.Observation result

We ware able to observe significant dense PM2.5 clusters in Japan.

9246-33, Session PS

Raman Lidar characterization using a reference lamp

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The determination of the amount of water vapor in the atmosphere using LIDAR is a calibration dependent technique, Different collocated instruments are used for this purpose, like radiossoundings and microwave radiometers. When there are no collocated instruments available, an independente lamp mapping calibration technique can be used.

Aiming to stabilish an independ technique for the calibration of the six channels Nd-YAG Raman Lidar system located at the Center for Lasers and Applications (CLA), São Paulo, Brazil, an optical characterization of the system was first performed using a reference tungsten lamp. This characterization is useful to identify any possible distortions in the interference filters, telescope mirror and stray light contamination.

In this paper we show three lamp mapping caracterizations (01/16/2014, 01/22/2014, 04/09/2014). The first day is used to demostrate how the tecnique is sensible to the position of the filters, the second one how it is useful to detect stray light and the third one demostrates a well optimized optical system.

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9247-1, Session 1

Parallel random selection and projection for hyperspectral image analysis

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Random projection (RP) is a computationally efficient and data-independent method for dimensionality reduction. The transformation matrix of RP generally includes random vectors, which may be mutually orthogonal unit ones. Theoretical results indicate that RP can well preserve distances among data points as well as the structure of data cloud. Recently, RP is of great interest because the mathematical theory of popular compressed sensing shows that sparsely representable signals can be recovered exactly from RP.

It has been demonstrated that using RP-based dimensional-reduced data can provide similar or even better result in linear unmixing, target detection, and classification. However, due to the random nature, the result of each run may not generate a satisfying result; instead, fusion of the results from multiple runs can yield a robust final result.

The aforementioned framework on decision fusion with multiple runs of RP is suitable to parallel computing. In this paper, we will investigate the implementation of graphics processing unit (GPU) to expedite the overall algorithm. It will be shown that the GPU implementation can provide significant speedup with the flexibility of using multiples runs to improve the data analysis performance.

9247-2, Session 1

FPGA-based architecture for hyperspectral endmember extraction

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Hyperspectral imagery is a continuously growing area in remote sensing applications. The spectral range extending from the visible region through the near-infrared and mid-infrared in hundreds of narrow contiguous bands, provides a very high spectral resolution, which allows the detection and the discrimination between different chemical elements of the observed image. These instruments, because of their potential in remote sensing applications, such as, target detection for security/militar purposes, hazard prevention, and monitoring oil spills among others, have been incorporated in satellite missions. In most of those applications, one of the requirements of paramount importance is the ability to give real-time or near real-time response.

Although, these sensors allow to capture large data cubes, for instance Hyperion sensor produces a 56x6925x242 in 30 seconds, the available downlink bandwidth to ground stations is limited, which brings prohibitive delays that endanger the real-time or near real-time requirements of such applications.

Recently, onboard processing systems have emerged, in order to overcome these delays between hyperspectral image acquisition and it interpretation. Such systems need to have high computational performance, compact size, reduced weight and low power consumption among other characteristics. Additionally, it is desirable that those onboard systems could also be flexible in order to be adaptable to the needs of different missions.

Field-programmable gate arrays (FPGA) represent the best choice to achieve the above mentioned requirements.

In recent years, scientific community have proposed several FPGA implementations of hyperspectral processing techniques, namely for unmixing, for clustering, among others.

The principal problem of hyperspectral images are the low spatial resolution due to the instantaneous field of view (IFOV), thus, the pixel ground size can vary from a few to tens of meters. This means that each pixel is a mixture of several spectrally distinct materials (also called endmembers). This paper proposes a parallel method designed for FPGA, to extraction of endmembers. This method is based on the Vertex Component Analysis (VCA) which assumes that each pixel contains a linear mixture of the endmembers present in the scene, thus the vertices of the simplex that contains the data correspond to the endmembers signatures. This method has several advantages, namely it is unsupervised, fully automatic, and it works with and without dimensionality reduction (DR) pre-processing step. This is of paramount importance since the DR step amounts to compute the eigen-values of the correlation matrix of the dataset.

The method herein proposed, projects the pixels onto a direction orthogonal to the subspace spanned by the endmembers already determined. The new endmember signature corresponds to the extreme of the projection. Additionally, a QR decomposition is made in order to reuse the orthogonal vectors on each iteration.

Experimental results, conducted on a Xilinx Zynq board with a Zynq-7020 SoC FPGA based on the Artix-7 FPGA programmable logic, using both simulated and real hyperspectral data sets and spectral libraries publicly available, indicate the potential of the proposed platform to implement high-performance, low cost embedded systems. This opens new perspectives for onboard hyperspectral image processing.

9247-3, Session 1

Intel Many Integrated Core (MIC) architecture optimization strategies for a memory-bound Weather and Research Forecasting (WRF) Goddard microphysics scheme

Jarno Mielikainen, Bormin Huang, Allen Huang, Univ. of Wisconsin-Madison (United States)

The Weather Research and Forecasting (WRF) model is designed for numerical weather prediction and atmospheric research. The WRF software infrastructure consists of several components such as dynamic solvers and physics schemes. Numerical models are used to resolve the large-scale flow. However, subgrid-scale parameterizations are for an estimation of small-scale properties (e.g., boundary layer turbulence and convection, cloud microphysics, radiation). Those have a significant influence on the resolved scale due to the complex nonlinear nature of the atmosphere.

In the Goddard microphysics scheme, a single hydrometeor category to simulate both graupel and hail. Another unique feature of the Goddard scheme is that the the assumed snow size distribution depends on both ice water content and temperature and is represented as a sum of an exponential and gamma distributions. There are no interactions among multiple horizontal grid points. Therefore, the scheme is very suitable for massively parallel computation. For that reason, the Goddard scheme is chosen as the microphysics scheme we optimized for Intel Many Integrated Core (MIC), which ushers in a new era of supercomputing speed, performance, and compatibility. It allows the developers to run code at trillions of calculations per second using a familiar programming model. Getting a good performance required properly-tuning an existing Fortran code to efficiently utilize multiple cores, the wide vector operations and make efficient use of the memory. Those optimization issues are discussed in this paper.

9247-4, Session 1

FPGA implementation of the hyperspectral Lossy Compression for Exomars (LCE) algoritm.

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The increase of data rates and data volumes in present remote sensing payload instruments, together with the restrictions imposed in the downlink connection requirements, represent at the same time a challenge and a must in the field of data and image compression. This is especially true for the case of hyperspectral images, in which both, reduction of spatial and spectral redundancy is mandatory.

Recently the Consultative Committee for Space Data Systems (CCSDS) published the Lossless Multispectral and Hyperespectral Image Compression recommendation (CCSDS 123), a predictive based technique resulted from the consensus of its members. Although this standard offers a good tradeoff between coding performance and computational complexity, the appearance of future hyperspectral and ultraspectral sensors with vast amount of data imposes further efforts from the scientific community to ensure optimal transmission to ground stations based on greater compression rates. Furthermore, hardware implementations with specific features to deal with solar radiation problems play an important role in order to achieve real time applications. In this scenario, the Lossy Compression for Exomars (LCE) algorithm emerges as a good candidate to achieve these characteristics. Its good quality/compression ratio together with its low complexity facilitates the implementation in hardware platforms such as FPGAs or ASICs.

In this work the authors present the implementation of the LCE algorithm into an antifuse-based FPGA and the optimizations carried out to obtain the RTL description code using CatapultC, a High Level Synthesis (HLS) Tool. Experimental results show an area occupancy of 75% in an RTAX2000 FPGA from Microsemi, with an operating frequency of 53 MHz. Additionally, the power budget obtained is presented giving an idea of the suitability of the proposed algorithm implementation for onboard compression applications.

9247-5, Session 1

EM scattering from a 2D target above a 1D sea surface using GPU-based FDTD

Lixin Guo, Chungang Jia, Pangju Yang, Xidian Univ. (China)

Investigation on the composite electromagnetic scattering from the target above a randomly rough surface has become a popular topic with its significant applications in the fields of remote sensing, target identification and radar detection. It is tough to solve this composite problem due to the complex interactions between the randomly rough surface and the target above or below it. GPU-accelerated parallel FDTD method is presented to study the composite scattering characteristic of bistatic scattering coefficient (BSC) from 2-D target above 1-D rough sea surface.

Compared with other numerical methods, the FDTD method has its own advantages in analysing the scattering from the composite model. The electrically large target and large scale rough surface lead to large numbers of unknowns. The traditional FDTD method is too week to deal with such problems due to limitation of computation time. The MPI-based parallel FDTD, was presented by J. Li et al. Using the method, the computation time is extremely reduced compared to sequential implementation. However, the speedup ratio of MPI-based method is limited by the high cost of the hardware. Fortunately, Compute Unified Device Architecture (CUDA) technology based on GPU has been extensively implemented for the large scale FDTD simulations successfully. Compared to the MPI technology, graphic processor unit (GPU) can achieve huge speedup ratios at low cost for its powerful computing capability, which motives us into adopt the GPU-based FDTD technology to extend the application of FDTD method in analysing the composite scattering from the target above a 1-D rough surface. Up to now, to our knowledge, few works have been reported to solve this problem using the GPU-based FDTD implementation. Additionally, a uniaxial perfectly matched layer (UPML) medium is employed to truncate the FDTD lattices, and the finite-difference equations in the UPML medium are used for the total computation domain making the parallel algorithm convenient to implement. In this paper, the precision of calculations performed on both GPU and CPU is single precision arithmetic.

9247-6, Session 2

Hybrid DWT-DCT based digital image watermarking for copyright protection of DubaiSat-2 images

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Due to the rapid development in the field of network technology and the convenient use of digital cameras and scanners in capturing digital images, the transmission, distribution and access of digital images over the internet have become so easy. Along with the increasing spread of images, a copyright protection has become a vital need. Therefore, digital watermarking technology is considered as the most efficient way to solve this issue. Digital watermarking is a process of adding an extra layer of protection through embedding a piece of digital information called “watermark” into different kinds of multimedia such as text, image, audio and video. The watermark can be either textual data or logo which identifies the owner or it’s copyright. So, this protects the rights of the owners against illegal and unauthorized usage. Digital watermarking has various applications in today’s world such as copyright protection, medical imaging, source tracking, broadcast monitoring, etc. In this paper, a novel blind hybrid watermarking algorithm is proposed using the Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) to provide better imperceptibility in harmony with the human visual system, and higher robustness against signal processing attacks. The proposed hybrid watermarking algorithm has been tested on DubaiSat-2 images with 1 meter resolution by using colored EIAST logo as a watermark. The experimental results show that the proposed hybrid algorithm is robust against different kinds of attacks such as JPEG compression, scaling, filtering, rotation and synchronization. The proposed algorithm is causing a minimal invisible distortion to images and the watermarked images have good transparency. The performance of the proposed algorithm is assessed by using Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measurement (SSIM), while the extracted watermark information is analyzed using Normalized Correlation (NC).

9247-7, Session 2

Building high-performance system for processing a daily large volume of Chinese satellite imagery

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Data and Applications (China); Yubin Xin, PCI Geomatics (Canada)

The number of Earth observation satellites from China increases dramatically recently and those satellites are acquiring a large volume of imagery daily. As the main portal of image processing and distribution from those Chinese satellites, the China Centre for Resources Satellite Data and Application (CRESDA) has been working with PCI Geomatics during the last three years to solve two issues in this regard: processing the large volume of data (about 1,500 scenes or 1 TB per day) in a timely manner and generating geometrically accurate orthorectified products. After three-year research and development, a high performance system has been built and successfully delivered. The high performance system has a service oriented architecture and can be deployed to a cluster of computers that may be configured with high end computing power. The high performance is gained through, first, making image processing algorithms into parallel computing by using high performance graphic processing unit (GPU) cards and multiple cores from multiple CPUs, and, second, distributing processing tasks to a cluster of computing nodes. While achieving up to thirty (and even more) times faster in performance compared with the traditional practice, a particular methodology was developed to improve the geometric accuracy of images acquired from Chinese satellites (including HJ-1 A/B, ZY-1-02C, ZY-3, GF-1, etc.). The methodology consists of fully automatic collection of dense ground control points (GCP) from various resources and then application of those points to improve the photogrammetric model of the images. The delivered system is up running at CRESDA for pre-operational production and has been and is generating good return on investment by eliminating a great amount of manual labor and increasing more than ten times of data throughput daily with fewer operators. Future work, such as development of more performance-optimized algorithms, robust image matching methods and application workflows, is identified to improve the system in the coming years.

9247-8, Session 2

Implementation of the 5-layer thermal diffusion scheme in weather research and Forecasting model with Intel many integrated core (MIC) architecture

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For weather forecasting and research, the Weather Research and Forecasting (WRF) model has been developed, consisting of several components such as dynamic solvers and physical simulation modules. WRF includes several Land-Surface Models (LSMs). The LSMs use atmospheric information, the radiative and precipitation forcing from the surface layer scheme, the radiation scheme, and the microphysics/convective scheme all together with the land's state variables and land-surface properties, to provide heat and moisture fluxes over land and sea-ice points. The WRF 5-layer thermal diffusion simulation is an LSM based on the MM5 5-layer soil temperature model with an energy budget that includes radiation, sensible, and latent heat flux. The WRF LSMs are very suitable for massively parallel computation as there are no interactions among horizontal grid points. The features, efficient parallelization and vectorization essentials, of Intel Many Integrated Core (MIC) architecture allow us to optimize this WRF 5-layer thermal diffusion scheme. In this work, we will present the results of the computing performance on this scheme with Intel MIC architecture.

9247-9, Session 2

A composite algorithm for variable size object tracking for high performance FPGA-based on-board vision systems

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Object tracking is one of the most significant tasks in on-board vision systems. There are a lot of well-known tracking algorithms based on several approaches such as: template matching, Bayesian segmentation, motion extraction et?. However, all these algorithms have the restrictions caused by an object size. In the case of continuous object tracking the target size can be significantly changed. The minimal object size can be equal to one pixel. The maximal size is much more than the field of view of the video sensor. The proposed algorithm can be used under these conditions.

The described composite algorithm includes two basic object tracking algorithms. The first algorithm is used to track small targets. In terms of this work, the small objects are equal or larger then a pixel but less than 15% of an image size. The other objects are called big-sized. The algorithm is based on the motion extraction method. The first stage of this algorithm is an estimation of frame-to-frame image transformation parameters. At the next stage the estimation of image background is calculated or updated. The third stage of the algorithm is the adaptive thresholding of the difference between the current frame image and the background image. At the forth stage the binary image obtained at the previous stage is marked. The final stage is an estimation of the object parameters: position, size and configuration.

The second algorithm is used for tracking the big-sized objects. It is based on structural methods and a template matching. The first stage of this algorithm is the extraction of a number of small-sized (approx. 32x32 pixels) reference zones. At the next stage the algorithm estimates positions of these zones in the current frame image. The third stage is the estimation of frame-to-frame object transformation parameter based on reference zone positions. The final stage is the estimation of object parameters.

Switching between two basic algorithms is occurred when the object size reaches the defined limit. In this case, the object parameters and image estimation results obtained from the current tracking algorithm are using to initialize another tracking algorithm.

The described algorithm is designed for a family of on-board vision systems with common architecture. The structure of the particular system depends on a vehicle type and the list of solving tasks. Typically, the system consists of top-level DSP (TI 320 series, AD TigerShark series) and 1-4 FPGAs (Xilinx Virtex, Virtex II or Virtex 5). FPGAs are used for performing the most of "heavy" operations such as spatial and temporal image filtering, geometric and spectral transformations, template matching and thresholding, binary image marking and SLAE solving. The DSP is used performing unique operations with small amount of data, FPGA dispatching and internal control.

The reference implementation of the proposed algorithm was evaluated on the set of synthesized and natural videos, received from the video cameras and the thermal imager. The algorithm demonstrates good reliability and accuracy of object parameter estimation.

9247-10, Session 2

Parallel motion JPEG2000 decoding running on multicore CPUs and CUDA-enabled GPUs

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This paper presents a parallel implementation architecture of Motion JPEG2000 decoding for data stream downloaded from a high speed encoding hardware. This architecture is based on joint usage of the multi-core CPU and GPU. By splitting the decoding system into two parts which are accelerated with different parallel schemes, both the computational power of the CPU and GPU are exploited. More specifically, the system processes a number a data frames in parallel with the GPU dedicated to perform the inverse discrete wavelet transform of these frames one by one and the CPU in charge of the rest parts of the decoding process, each frame a thread. The experiments demonstrate that the proposed architecture is able to process 1024x1024 images at 166 frames per second, which delivers real-time decoding for the encoder and outperforms other famous implementations such as Jasper and Kakadu.

9247-11, Session 3

Initial results on computational performance of Intel Many Integrated Core (MIC) architecture: implementation of the Weather and Research Forecasting (WRF) Purdue-Lin microphysics scheme

Jarno Mielikainen, Bormin Huang, Allen Huang, Univ. of Wisconsin-Madison (United States)

Purdue-Lin scheme is a relatively sophisticated microphysics scheme in the Weather Research and Forecasting (WRF) model. The scheme includes six classes of hydro meteors: water vapor, cloud water, raid, cloud ice, snow and graupel. The scheme is very suitable for massively parallel computation as there are no interactions among horizontal grid points. In this paper, we accelerate the Purdue Lin scheme using Intel Many Integrated Core Architecture (MIC) hardware. The Intel Xeon Phi coprocessor is the first product based on Intel MIC architecture, and it consists of up to 61 cores connected by a high performance on-die bidirectional interconnect. The coprocessor supports all important Intel development tools. Thus, the development environment is familiar one to a vast number of developers. Although, getting a maximum performance out of MICs will require using some novel optimization techniques. Currently, the Xeon Phi is connected to a CPU via the PCI Express (PICe) bus. However, a MIC on a socket will be available in the near future. Therefore, future MICs do not have to deal with issues related to data transfer over PCIe. In this paper, we will discuss in detail the code optimization issues encountered while tuning the Purdue-Lin microphysics Fortran code for Xeon Phi. In particularly, getting a good performance required utilizing multiple cores, the wide vector operations and make efficient use of memory.

9247-12, Session 3

GPU efficient SAR image despeckling using mixed norms

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Speckle noise which is inherent to Synthetic Aperture Radar (SAR) imaging obstructs various image exploitation tasks such as edge detection, segmentation, change detection, and target recognition. Therefore, speckle reduction is generally used as a first step which has to smooth out homogeneous regions while preserving edges and point scatterers. Traditional speckle reduction methods are fast and their memory consumption is insignificant. However, they are either good at smoothing homogeneous regions or preserving edges and point scatterers. State of the art despeckling methods are proposed to overcome this trade-off. However, they introduce another trade-off between denoising quality and resource consumption thereby higher denoising quality requires higher computational load and/or memory consumption. In this paper, a local pixel-based total variation (TV) approach is proposed which combines l2-norm and l1-norm in order to improve despeckling quality while keeping execution times reasonably short. Pixel-based approach allows efficient computation model with relatively low memory consumption. Their parallel implementations are also more efficient comparing to global TV approaches which generally requires numerical solution of sparse linear systems. However, pixel-based approaches trapped to local minima frequently hence despeckling quality is worse comparing to global TV approaches. Proposed method, namely mixed norm despeckling (MND), combines l2-norm and l1-norm in order to improve despeckling performance by alleviating local minima problem. All steps of the MND are parallelized using OpenMP on CPU and CUDA on GPU. Speckle reduction performance, execution time and memory consumption of the proposed method are shown using synthetic images and TerraSAR-X spot mode SAR images.

9247-14, Session 3

Acceleration of the Partitioned Predictive Vector Quantization Lossless Compression Method with Intel MIC

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It has been shown that the partitioned predictive vector quantization (PPVQ) algorithm can provide high compression ratio for lossless compression of the ultraspectral sounder data with high spatial and spectral resolutions. With the advent of the multicore technologies, parallelization of several parts of the algorithm has been explored in previous work using a compute unified device architecture (CUDA) based environment on the Graphics Processing Unit (GPU). Recently the Intel Many Integrated Core (MIC) architecture on a coprocessor is introduced which shows promise in handling more divergent workloads compared to GPU as needed in PPVQ. Therefore we will explore the parallel performance of the MIC-based implementation. The speedup will be measured with respect to a single core CPU for evaluation.

9247-15, Session 3

Fast motion detection in coded video streams for a large-scale remote video sensor system

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A large number of remote video sensors are being deployed in the world to collect, store, and analyze the real-world data. Since a remote video sensor produces very large data compared to text data, the total amount of video data are extremely large in size, complexity, and capacity. Since a centralized system is required to manage large-scale video data, it might be expensive to install that kind of system. Therefore, we present a fast video processing method to handle large-scale video data, which also contributes to reduction of computational complexity and the system installation cost.

Important events from a remote video sensor are closely related to a motion in video. To detect the motion, a comprehensive survey of motion detection algorithms in a pixel domain was provided. The pixel domain approaches are a great potential for reliable motion detection but, it has a serious disadvantage in a large-scale remote video sensor system where all video data should be full decoding, so that it handicap the system performance. Another approach is a compressed-domain approach where avoids the full decoding and reconstruction of the video, which provides a

potential for real time processing of multiple video streams. But, the most of compressed-domain approaches extract and manipulate the motion vector information per pixel from a coded video sequence. It might cause a processing burden when the resolution and the frame per second of a coded video sequence are getting increased.

In this paper, we present a fast motion detection method based on the number of bits and a coded block pattern used for encoding a video stream. In MPEG-derived video coding standard, a motion in a video sequence needs more bits than a video sequence with no motion does during a video encoding process. A low complexity measurement of the number of bits is performed in the coded video sequence and then, we store and process the coded video stream only if the total bits are larger than a pre-defined threshold. We also use a coded block pattern to improve the robustness to noise. Since a scene changes or a new object appears in a video sequence, the video coding standard includes an intra-coded block in coded video sequence. Manipulation of the number bits and the coded block pattern are itself a much easier task than full reconstruction of each pixel of a video frame and it can save storage cost because it only stores a coded video sequence with a motion. The proposed method also contributes to reduction of computational complexity compared to the manipulation of motion vectors per a pixel unit.

To evaluate our method, we deployed a centralized single server connected to 64 H.264 capable remote video sensors. We conducted a wide range of performance comparison how the method work efficiently compared to the existing work. Results on the test sequences showed that the proposed method can process more video sequences than the pixel-domain approach can irrespective of GPU used and the compressed-domain approach with the motion vector manipulation can.

9247-16, Session 4

GPU-accelerated computation of beam scattering from sea surface

Xiang Su, Xiaoxiao Zhang, Zhensen Wu, Xidian Univ. (China)

Microwave backscattering from sea surface is important in predicting radar detection of targets on or near the surface, since the probability of a false alarm depends upon the observed signal-to-clutter ratio. Scattering from sea surface at small and moderate incident angles can be reasonably explained by Bragg scattering mechanism. However, the mechanism of scattering from sea surface at low grazing angle (LGA) which often leads to strong echo signal called “sea spike” are still not clear. The problem of electromagnetic wave scattering from randomly rough surfaces is mainly divided into two approaches. Analytical models, such as Kirchhoff approximation (KA), small perturbation method (SPM) et al, and numerical methods used in this paper. However the large area illuminated by incident beam at LGA leads to a number of unknown when using numerical method. In addition, the calculation of backscattering from hundreds of random sea surface samples is needed to obtain the statistical properties of random rough surface. This paper first introduces beam simulation method (BSM) using a number of narrow beams to simulate a large beam. The representations of nominal and synthetic beam are illustrated and demonstrate that when the number of narrow beams is sufficient the simulation is correct. Using narrow beams to construct a large beam can independently calculates the backscattering field illuminated by narrow beams to effectively decrease memory required and executed time. GPU with compute unified device architecture (CUDA) has the advantages of the massively parallel computation, easily generating hundreds and thousands of threads. Every thread calculates the scattering electromagnetic field by a small beam and every block consisting of hundreds threads obtains the scattering electromagnetic field from a sea surface sample by adding the results from its threads. Then, transfer the results from device to host and get the statistical average on host.

9247-17, Session 4

A novel highly-parallel algorithm for linearly unmixing hyperspectral images

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Endmember extraction and abundances calculation represents critical steps within the process of linearly unmixing a given hyperspectral image because of two main reasons. The first one is due to the need of computing a set of accurate endmembers in order to further obtain confident abundance maps. The second one refers to the huge amount of operations involved in this time-consuming process.

This work proposes an algorithm to estimate the endmembes of the hyperspectral image under analysis and its abundances at the same time. The main advantage of this algorithm is its high parallelization degree and the mathematical simplicity of the operations implemented.

This algorithm estimates the endmembers as virtual pixels. The algorithm performs the descent gradient method to iteratively refine the endmembers and the abundances, reducing the mean square error, according with the linear unmixing model. Some mathematical restrictions are added so the method converges in a unique and realistic solution. According with the algorithm nature, these restrictions can be easily implemented.

The results obtained with synthetic images demonstrate the well behavior of the algorithm proposed. Moreover, the results obtained with the well-known Cuprite dataset also corroborate the benefits of our proposal.

9247-18, Session 4

The backscattering characteristics and accelerated arithmetic for complex rough target in THz and laser bands

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The coherent and incoherent scattering are composed in the backscattering characteristics of arbitrarily shaped dielectric object with rough surface both in laser and THz bands. If the radius of curvature at any point of the surface is much greater than the incident wavelength which is also longer than the surface height fluctuation and RMS of surface slope, the Kirchhoff approximation and Physical optics method, as well as the stationary phase evaluation are invited here to deduce the analytical expression of coherent backscattering cross section of rough dielectric object. Basically, the coherent cross section can be viewed as the combination of the RCS of corresponding smooth and perfectly conducting object, the Fresnel reflection coefficient of dielectric surface and the characteristic function of rough surface. Thus, the scattering expression of rough conducting object, smooth dielectric object and the rough dielectric object can be logically obtained. Using the tangent plane approximation, the surface of the object is divided into a series of patches, and then the incoherent component is achieved by integrating over the illuminated area combined with the covering function. Based on the Physical optics approximation and GPU parallel computing, the coherent scattering component of smooth conducting object, the incoherent component of rough object and its corresponding backscattering cross section can be easily computed. In this paper, we numerically simulate the backscattering characteristics in laser and THz bands of rough dielectric sphere, lambertian sphere and other complex rough dielectric targets respectively, meanwhile, we also analysis the influence of dielectric coefficient and roughness concentration on the results of the backscattering cross section.

9247-19, Session 4

Application of Intel many integrated core (MIC) architecture to the Yonsei University planetary boundary layer scheme in Weather Research and Forecasting model

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The Weather Research and Forecasting (WRF) model provided operational services worldwide in many areas and has linked to our daily activity, in particular during severe weather events. The scheme of Yonsei University (YSU) is one of planetary boundary layer (PBL) models in WRF.

The PBL is responsible for vertical sub-grid-scale fluxes due to eddy transports in the whole atmospheric column, determines the flux profiles within the well-mixed boundary layer and the stable layer, and thus provide atmospheric tendencies of temperature, moisture (including clouds), and horizontal momentum in the entire atmospheric column. The YSU scheme is very suitable for massively parallel computation as there are no interactions among horizontal grid points. To accelerate the computation process of the YSU scheme, we employ Intel Many Integrated Core (MIC) Architecture as it is a multiprocessor computer structure with merits of efficient parallelization and vectorization essentials.

The optimization results of this scheme using Intel MIC architecture will be delivered.

9247-20, Session 4

Efficient parallel implementation of polarimetric synthetic aperture radar data processing

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This work investigates the parallel implementation of polarimetric synthetic aperture radar (POLSAR) data processing. Such processing can be computationally expensive when large data sets are processed. However, the processing steps can be largely implemented in a high performance computing (HPC) environment. In this work, we studied the different aspects of the computations involved in processing the POLSAR data and developed an efficient parallel algorithm. POLSAR data is often represented as a 3X3 complex coherence matrix (T) which embeds all the information pertaining to the different polarization combinations which in turn characterize the scattering behavior in a pixel. For unsupervised analysis of POLSAR data, the coherence matrix is decomposed using an appropriate method to characterize the scattering behavior at the surface. One of the most commonly used decomposition algorithms is the Entropy-Alpha-Anisotropy (H/?/A) decomposition which can be used to cluster the POLSAR data into 16 classes. Calculating H, ? and A requires eigenvalue decomposition of the complex coherence matrix at every pixel. The algorithm is implemented using message parsing interface (MPI) protocol and is tested on a parallel cluster with four nodes. The implementation is also tested on a cluster of four nodes with eight cores each providing 32 processing threads. Linear speed-ups are achieved in all the cases. It was noted that the speed-up for big data sets is similar to the number of processing threads. While the speed-up when using only 4 nodes is always close to 4X, the speed-up while using 4 nodes with 8 cores each gets closer to 27.27X for a dataset of size 4096X4096 up from 5.31 for a small data set (256X256). More experiments will be conducted for accurately determining the efficiency of the parallel algorithms. A GPU implementation will also be developed.

9247-21, Session 4

GPU-accelerated the geometric modeling of the ocean surface based on ocean wave spectrums

Zhan Song, Jiaji Wu, Wenze Li, Longxiang Ling-Hu, Xiang Su, Zhensen Wu, Xidian Univ. (China)

Ocean surface modeling technique, the key technique in the research on the electromagnetic wave scattering of ocean surface, has been proposed in different papers. One of the most attractive schemes is the linear superposition method based on the linear ocean wave theory. However, it requires high computational effort to achieve the numerical simulation on the two-dimensional time-evolving ocean waves. With the emergence of the GPU and the development of the Compute Unified Device Architecture platform (CUDA), an attractive candidate can be adopted to expedite the computation process. Thus, an efficient GPU-based numerical simulation of ocean surface using the linear superposition methods was proposed in this paper. Because all sampling points from ocean surface which need to be calculated have no dependence, each sampling points is assigned to independent thread in the parallel version. In order to gain the maximum throughput, memory access and data transmission were carefully designed. Through CPU and GPU heterogeneous computing, the parallel version achieves very high speedups, compared with its single-thread CPU counterpart. We therefore conclude that GPU computing for large-scale simulation of ocean surface is a promising approach.

9247-22, Session 5

Optimizing an advanced research weather research and forecast (WRF-ARW) dynamics subroutine for Intel MIC

Jarno Mielikainen, Bormin Huang, Allen Huang, Univ. of Wisconsin-Madison (United States)

The Weather Research and Forecast (WRF) model is the most widely used community weather forecast and research model in the world. There are two distinct varieties of WRF. Advanced Research WRF (WRF-ARW) is an experimental, advanced research version featuring very high resolution. The WRF Nonhydrostatic Mesoscale Model (WRF-NMM) has been designed for forecasting operations. WRF consists of dynamics code and several physics modules. The WRF-ARW core is based on an Eulerian solver for the fully compressible nonhydrostatic equations. In the paper, we will use Intel MIC to substantially increase the performance of the most time consuming subroutine in the WRF-ARW dynamics core. We will also describe the challenges we meat during the development of a high-speed dynamics code subroutine for Intel MIC. Furthermore, lessons learned from the code optimization process will be discussed.

9247-23, Session 5

On the use of reconfigurable hardware for the estimation of the number of end-members in hyperspectral images

Carlos Gonzalez, Univ. Complutense de Madrid (Spain); Sebastian López, Roberto Sarmiento, Univ. de Las Palmas de Gran Canaria (Spain); Daniel Mozos, Univ. Complutense de Madrid (Spain)

Spectral unmixing is an important task for remotely sensed hyperspectral data exploitation. It amounts the identification of pure spectral signatures (endmembers) in the data, and the estimation of the abundance of each endmember in each (possibly mixed) pixel. A challenging problem in spectral

unmixing is how to determine the number of endmembers in a given scene.

For this purpose, many algorithms have been proposed in the recent literature, being the estimation of the Virtual Dimensionality (VD) of the hyperspectral image and the hyperspectral signal subspace estimator (HySime) two of the most popular choices. Unfortunately, the high dimensionality of the hyperspectral data provided by modern sensors as well as the inherent computational complexity clearly make the use of these algorithms prohibitive for applications under real-time or near real-time constraints. Hence, the utilization of high performance computing platforms in order to accelerate the process of unmixing a hyperspectral image becomes mandatory for such scenarios.

For this purpose, reconfigurable hardware solutions such as field programmable gate arrays (FPGAs) have consolidated during the last years as one of the preferred choices for the fast processing of hyperspectral remotely sensed images due to the following three main reasons. First, because of their smaller size, weight and power consumption when compared with other high performance computing systems, such as clusters of computers, multicore processors and/or graphical processing units (GPUs). The second reason becomes motivated by the current availability of FPGA devices with increased levels of tolerance to ionizing radiation in space, which converts them into the - nowadays - sole possible solution for onboard processing at earth observation satellites. The last but never the least reason comes from the fact that FPGAs have the inherent ability to change their functionality through partial or full reconfiguration. This last characteristic extends the useful life of remote sensing autonomous systems, since FPGAs permit changes to the usage model and the data processing paradigm in space rather than hard-coding of all components prior to launch.

This paper uncovers two FPGA-based architectures for accelerating the process of estimating the number of endmembers that constitute a hyperspectral image according to the VD and the HySime algorithms. The proposed methods have been implemented on a Virtex-7 XC7VX690T FPGA and tested using real hyperspectral data collected by NASAs Airborne Visible Infra-Red Imaging Spectrometer (AVIRIS) over the Cuprite mining district in Nevada and the World Trade Center in New York. Experimental results demonstrate that the VD implementation exhibits real-time performance while the HySime implementation exhibits near real-time performance. Both implementations significantly outperform a software version, which makes our reconfigurable system appealing for onboard hyperspectral data processing.

9247-24, Session 5

GPU-based Calculation of Scattering Characteristics of Space Target in the Visible Spectrum

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Scattering characteristics of satellites in the visible spectrum, which can be used in space docking, is calculated in this paper. During the calculation, satellites are modeled with thousands of triangularfacets. In order to obtain scattering characteristics of satellites in the visible spectrum, calculation of each facet will be needed. For each facet, calculation will be executed in the spectrum of 400-760 nanometers at intervals of 1 nanometer. Thousands of facets and hundreds of bands of each facet will cause huge calculation, thus calculation of scattering characteristics of satellites in the visible spectrum will be very time-consuming. The emergence of GPU and the development of the Compute Unified Device Architecture platform (CUDA), throw new light on the time-consuming problem. Thus, GPU is used to accelerate the calculation. In our implementation, each thread is used to calculate scattering from each facet in a given spectrum. Reduction is first done within each block. Then the array containing partial reductions is transferred back to host and added there to get the total scattering radiance. Shared memory is used to buffer solar irradiance to reduce access to global memory, and configuration of grid and block is tuned to get the best performance. Compared with single-thread CPU program, the parallel version achieves very high speedups.

9247-25, Session 5

GPU-based rectification of high-resolution remote sensing stereo images

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One of the major challenges in topographic mapping, 3D reconstruction, or generation of digital terrain models from stereo aerial photographs or satellite images is the stereo rectification preprocessing step that is required in non-canonical stereo configuration. The general case is the use of extrinsic (3D geographic position and rotation) and intrinsic (principal point, focal point, and distortion) parameters from each calibrated camera, in order to establish canonical epipolar geometry, where each image's horizontal scan lines are parallel to the stereo pair's collinear epipolar lines. In stereo vision analysis this significantly reduces the search space of the corresponding pixel level feature matching (i.e. disparities) on both images, in order to perform consequent 3D reconstruction phase. Stereo rectification consists of geometric sub-pixel transformation and image resampling, where the missing pixels are interpolated. Such transformation is infeasible when dealing with high-resolution stereo imagery due to high memory requirements and high computational load. This presents an increasingly evident problem, since the remote sensing technologies are increasingly becoming more accurate, causing even higher computational demands. The Graphics Processing Units (GPUs) are a viable alternative to solve this problem, due to increasing parallel computational power and lower investment costs. In this paper, a novel method for fast stereo images pairs' rectification to epipolar geometry by using General Purpose computing on GPU (GPGPU) is proposed. The method was implemented with NVIDIA's Compute Unified Device Architecture (CUDA) technology, and is capable to transform extremely high-resolutional data, due to efficient out-of-core processing, where the data is streamed and processed simultaneously on the GPU. Comparison was made between the GPU-based and multi-core CPU methods for over 400 of stereo aerial photographs with the resolution of 20010 x 13080 pixels, resulting in over 800 GB of data to be processed. In the experimental results we will show that the newly proposed method achieves a significant speedup in regards to multicore CPU-based processing.

9247-26, Session 5

Minimum Access Division Free Structure for GPU accelerated parallel FDTD

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As a powerful tool for computational electromagnetics, finite difference time domain (FDTD) has been widely applied in the simulation of wave propagation, scattering, and antenna radiation in the design of remote sensing systems.

The main bottom-neck of the FDTD technique is the computational complexity. Recent years, a lot of techniques have been proposed to accelerate the FDTD technique via parallel computing, especially on the GPU platform. One of the most time-consuming modules in FDTD is the convolutional perfectly matched layer (CPML). In this paper, we reveal two main redundancies in the current naïve GPU-accelerated CPML and propose a novel minimum-access division-free structure to further accelerate the CPML parallel implementation. Firstly, by reexamining the derivation of FDTD technique, we derive that the expensive division operator can be avoided by optimally rearranging the iteration process of CPML. This fundamentally

overcomes the computational redundancy of traditional CPML technique. The second redundancy is multiple memory access in the temporal updating of electric and magnetic field. In the traditional FDTD system, the updating steps are conducted independently with that in the CPML iterations. In this paper, these two updating steps are designed jointly in the purpose of minimizing the memory access.

Both theoretical and experimental evidence shows that the proposed minimum-access division free structure can save 70% operation time of the traditional GPU-CPML technique and does not affect the accuracy of at all.

9247-27, Session 5

GPU acceleration of incenter-based nearest feature space approach to hyperspectral image classification

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In this paper a novel technique, known as incenter-based nearest feature space (INFS) approach, is proposed for supervised hyperspectral image classification. This approach is developed for land cover classification based on the fusion of remotely sensed images of the same scene collected from multiple sources. The original NFS classifier is a time-consuming method when the number of hyperspectral bands and trainingtest samples are large. In geometry, the incircle of a triangle, which is tangent to its three sides and can form a nearest feature space (NFS), is the largest circle contained in the triangle. Instead of using the distances measured from the query points (test samples) to the projection points of the NFS, the proposed INFS measures the distances from the query points to the incenters of the NFS. Thus, compared to the original NFS classifier, the propose INFS can improve the execution time of NFS classification process. Moreover, in order to further speed up the computation performance, this paper proposes a parallel computing version of INFS, namely parallel INFS (PINFS), using a modern graphics processing unit (GPU) architecture with NVIDIA's compute unified device architecture (CUDA) technology to improve the computational speed of PINFS processes. Experimental results demonstrate the proposed INFS approach is suitable for land cover classification in earth remote sensing. It can improve the computation performance compared to original NFS classifier.

9247-28, Session PS

Salient region detection in remote sensing images based on frequency and color characteristics

Libao Zhang, Xuewei Li, Beijing Normal Univ. (China)

With the overwhelming number of remote sensing images available today, it is necessary to propose automatic algorithms for the detection of visually salient regions in remote sensing images. There are various applications for salient object detection, including biologically based methods and purely computational methods. Our method is based on a color information map, and a frequency domain analysis. This method outputs full resolution saliency maps with well-defined details. First, the features of color are exploited using the information content analysis, which provides an impressive result. Thus, all of the salient regions can be detected without mistaken detection of the inner part. Second, several spatial scales of an intensity map are created using a Gaussian pyramid, and the high frequency information of each scale is fused on the same scale. Thus, the details of the saliency maps can be detected in this process. Compared with existing models, our method can not only effectively extract detail of the salient region but also effectively remove mistaken detection of the inner parts of the saliency region.

9247-29, Session PS

A fine-grained parallel model of edge-directed interpolation for remote sensing image

Wenze Li, Jiaji Wu, Zhan Song, Xidian Univ. (China); Xiang Su, Xidian Univ. (China)

The edge-directed interpolation is widely used to enhance visual performance of remote sensing image. Compared with traditional bicubic interpolation and bilinear interpolation, a great number of matrix operations will appear as it is getting better visual performance. CUDA (Compute Unified Device Architecture) offers tremendous performance in many high-performance computing area. The edge-directed interpolation readily maps to this architecture (CUDA). However, parallel schemes based on CUDA are generally decomposed into coarse-grained tasks which are suitable for thread blocks. In this paper, a parallel algorithm of fine-grained scheme edge-directed interpolation is proposed. The process of parallel interpolation for one missing pixel based on CUDA is assigned to 4*4 threads for the reason that majority of the matrix operations are relate to 4*4 matrix. This task division strategy minimizes resource pressure of thread-blocks. Our calculating scheme is expressed in terms of increasing parallelism that is efficiently implemented on the GPU. By employing one NVIDIA GTX480 GPU in the case with I/O transfer, our GPU optimization efforts on the fine-grained edge-directed interpolation scheme achieve a speedup of 60.2x with respect to its CPU counterpart C code running on one CPU core of Intel core(TM) i7-920.

9247-30, Session PS

Detection and recognition of deep seismic weak reflection signal

Xie Kai, Yangtze Univ. (China)

Exploration objectives are diverted from middle, shallow to middle, deep gradually. The deep petroleum exploration has become the main object for the future.Years of deep exploration research study shows that the key to deeper exploration is possible to suppress a variety of noise interference , thus highlighting the weak reflection seismic signals effectively improve the signal to noise ratio and resolution of deep seismic signals. This project will focus on seismic weak reflection signal,and try to find new ways for the detection and recognition of deep seismic weak reflection signal, which improve the signal to noise ratio and resolution of deep seismic signals by multi-scale transformation.1) According to the analysis of the noise characteristics, deep noise model is established to achieve a qualitative expression of deep seismic noise sources.2)According to the analysis of the amplitude and spectral characteristics of deep seismic signals, the signal model of weak seismic reflection is established to achieve a quantitative expression of the weak seismic signals.3) we present the method of weak seismic signals based on multi-scale transformation, which will be verified by selected synthetic seismic data and deep seismic data. Our research will greatly enrich the weak signal identification methods and theories based on multi-scale transformation, and provide a new ideas for the deep exploration of oil and gas.

9247-31, Session PS

Scattering of targets over layered half-space using a semi-analytic method in conjunction with FDTD algorithm

Bing Wei, Xidian Univ. (China)

Finite-difference time-domain (FDTD) algorithm with a new method of plane wave excitation is used to investigate the RCS characteristics of targets over layered half space. Compare with the traditional excitation plane wave method, the calculation memory and time requirement is greatly decreased. The FDTD calculation is performed with a plane wave incidence, and the RCS of far field is obtained by extrapolating the currently calculated data on the output boundary. However, methods available for extrapolating have to evaluate the half space Green function. In this paper, a new method which avoids using the complex and time-consuming half space Green function is proposed. Numerical results show that this method is in good agreement with classic algorithm and it can be used in the fast calculation of scattering and radiation of targets over layered half space.

9247-32, Session PS

Estimating refractivity of lower troposphere from weather radar clutter

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Abstract: Echoes with anomalous propagation conditions seriously affect the quality of Doppler radar data. The vertical profile of refractivity determines the path of the radar beam and the incidence of clutter, which can be simulated by a physically model. Main drawback of traditional method of direct refractivity measurement by mean of radiosounding is its sparse sampling in time and space, particularly at lower altitudes in oceanic region. As a remote sensing method, Refractivity from clutter (RFC) technique can be applied to retrieve the lower atmospheric refractivity structure surrounding a radar using its sea clutter signal. The principle of RFC techniques is to search the parameters of the refractivity profiles by comparing the measured clutter with those generated from a family of assumed profiles. Signal simulation in the presence of a refractivity profile is usually solved by parabolic equation (PE) methods for electromagnetic wave propagation, and search process is directed by an estimation algorithm. We investigated the RFC which uses radar observations to infer refractivity conditions with better temporal resolution than the usual soundings. Mixed Fourier transform based parabolic equation approximation to the wave equation is used to compute sea surface echoes with varying index of refraction as the forward model. The inversion algorithm is implemented on weather radar data collected on the coast of the Yellow sea of China. A global search for the refractivity parameters is performed using an intelligent optimization algorithm, and parallel computing is adapted to accelerate the inversion.

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9248-1, Session 1

Energy harvesting for autonomous sensors *(Keynote Presentation)*

Christos Tsamis, National Ctr. for Scientific Research Demokritos (Greece)

No Abstract Available

9248-2, Session 2

Piezoelectric nanogenerators on flexible substrates for self-powered systems and sensors *(Invited Paper)*

Eleni Makarona, National Ctr. for Scientific Research Demokritos (Greece)

No Abstract Available

9248-3, Session 2

Nonlinear mechanical resonators for ultra-sensitive mass detection

Panos G Datskos, Nickloay Lavrik, Oak Ridge National Lab (United States)

The fundamental sensitivity limit of nanoscale mechanical resonator can approach one atomic mass unit when only thermal noise is present. However, measurements with nanoscale mechanical resonators is challenging due to the minuteness of their oscillation amplitudes and presence of noise sources in real experimental environments. In order to surmount these challenges, we explore microscale cantilever resonators driven to large amplitudes beyond the nonlinear instability onset. We demonstrate femtogram mass sensing that relies on a bifurcation point tracking, without the need for complex readout means. Our approach enables detection of mass changes near the fundamental limit imposed by thermomechanical fluctuations.

9248-4, Session 2

Superhydrophobic coatings for ammunition corrosion protection

Slobodan Rajic, Panos Datskos, Scott Hunter, Oak Ridge National Lab (United States)

Long-term storage of ammunition can result in unacceptable levels of corrosion that can lead to reliability and safety issues. During its lifecycle, ammunition can be exposed to marine environments and repeatedly restowed in ammunition cans after maritime patrolling. Salt water can be introduced into the ammunition cans, which could greatly accelerate the corrosion process. We have developed very thin and protective superhydrophobic coatings that are cost effective and substantially prolong the useful life of ammunition made from traditional materials. We have shown increases in some cases of over a factor of ten in corrosion resistance time in extremely corrosive salt fog environments. We have also examined the compatibility of these coating with the weapon environment and associated chemicals, such as lubricating oils, solvents, etc.

9248-5, Session 2

Spray-on superhydrophobic coatings with high mechanical durability for anti-corrosion and anti-soiling applications

Daniel Schaeffer, Georgios Polyzos, David Barton Smith, Scott Hunter, Oak Ridge National Lab (United States)

A superhydrophobic (SH) surface has many characteristics – of which are its self-cleaning and anti-corrosion functionalities – that are desirable across various industries. A superhydrophobic surface utilizes the right combination of surface chemistry and roughness that force water droplets to form high water contact angles (CA). This in turn allows droplets to easily roll off and pick up dirt and debris across the surface while also preventing water from penetrating the surface. We have developed a simple yet durable spray-on coating based on functionalized SiO2 nanoparticles that can easily be applied to surfaces including, but not limited to, optical sensors, photovoltaics, sights and lenses, textiles, construction materials, and electronic devices. In addition, these coatings exhibit practical mechanical and environmental durability that allow prolonged use of the coatings in harsh environments.

9248-7, Session 3

Sense and avoid radar for micro-/nano robots *(Invited Paper)*

Pavlo A Molchanov, Olha Asmolova, AETHER Inc (United States)

Fly eye sense and avoid radar can be very small, provides continuous surveillance of entire sky (360 degree by azimuth and elevation) and can be applied for separate or swarm of micro/nano UAS or UGS. Revolutionary new fly eye radar sensor technologies based on an array of directional antennas is eliminating the need for a mechanical scanning antenna or complicated phase processor. It radically decreases radar size, increases bearing accuracy several folds and can be multi-functional, multi-frequency. Directional antennas coupled with radar receivers can be distributed inside or between swarm members. Few points of view, using diversity signals and intelligent processing provides 3D recognition and targets classification due to its use of continuous (for CW radar) or five orders more pulses (for pulse radar) than any scanning radar to each space point. Low transmitting power and few orders higher sensitivity make proposed radar one step closer to passive radar “invisible” for missile sensors. Fly eye micro-radars are inexpensive, can be expendable. Distributed along a border or around a protected location (military facility and buildings, camp, stadium) small size, low power unattended radar sensors can be used for target detection and tracking, threat warning, pre-shot sniper protection and provides effective support for homeland security. The multi-band, multi-directional antenna array with separate receivers can provide a multi-functional separate signal processing and simultaneously can be used for radar, communications, command control, data link or navigation system. Micro-radars may be easy connected point-to-point to one or few operators and create invisible from outside network by enhanced SMART technology.

GPS receivers commonly employ an omni-directional antenna. This antenna provides a wide view of the sky and surrounding area. For a normal operating environment, the omni-antenna is the best choice for GPS receivers as they provide wide visibility for as many satellites as possible. For the GPS denied environment it is precisely the wrong antenna choice because it allows jammers and spoofers access to the receiver’s correlators thus corrupting the receiver’s ability to provide an accurate position solution.

A simple array of directional GPS antennas pointed away from the jammer will provide 20 to 30 db protection. This is comparable to what a perfectly aligned null from a phased array would provide. Of course the phased array cannot keep the optimal alignment in a dynamic environment and phased array's electronics' power, weight, size and cost are all negative factors when compared to a simple directional GPS antenna.

Array of directional antennas provides unique possibility for measurement of Direction of Arrival (DOA) and signal source space position (Monopulse antenna array technology) which can be used for source space position verification.

The directional antennas have higher gain, can be multi-frequency and connected to a multi-functional network. Prototype of fly eye radar with two directional antennas has been designed and bench tested.

9248-8, Session 3

Submicron metamaterial structures using drawn composite fibers

Daniel A Schaeffer, Panos Datskos, Oak Ridge National Lab (United States)

Technology often progresses by combining two or more unrelated or disparate components into a hybrid system. There are many optical phenomena that heavily rely on manipulation and constraint of electromagnetic fields in sub-wavelength metallic-dielectric resonator systems. There has also been an increasing trend for homogeneously combining multiple materials with contrasting optical, electronic, and thermo-mechanical properties in a single fiber paving the way of fibrous building blocks (FBBs). Multiple FBBs can be assembled into ordered 3D structures with high reproducibility through fiber drawing techniques. Artificial materials that are used to manipulate electromagnetic waves (metamaterials) can be fabricated by adapting and modifying existing fiber-drawing techniques leading to the design of new metallic-dielectric resonators for micro- and nano-scale optical devices and sensors.

9248-9, Session 3

Photonic crystal fiber long period grating sensor for ammonia detection in structural health monitoring

Shijie Zheng, Harbin Institute of Technology (China) and Harbin Institute of Technology (China); Jinping Ou, Harbin Institute of Technology (China)

Long-period gratings (LPGs) in photonic crystal fiber (PCF) offer excellent prospects for many diverse sensing applications. In this paper, we present a nano-film coated PCF-LPG ammonia sensor that has been developed with high sensitivity and selectivity for nondestructive detection in structural health monitoring. Two types of nano-films are coated in the grating region by electrostatic self-assembly (ESA) deposition processing. The primary bi-layer coatings of polyallylamine hydrochloride/ polyacrylic acid increase the sensitivity to refractive index change of the surrounding environment. The secondary bi-layer coatings of Zirconia/Poly-sodium 4-styrenesulfonate are for selectivity purpose, in this case to absorb ammonia molecules only. The proposed sensor is high sensitive to ammonia with negligible cross-sensitivity to moisture, methanol or acetone. It can also be further designed as multi-channel sensor system to monitor the concentration distribution for structural health conditions and safety through in situ measurements. Meanwhile, a numerical analysis of light power overlap of cladding modes with core mode has been investigated. The design to maximize the overlap can be established based on the PCF structure and the dependence of cladding modes.

9248-10, Session 3

Bi-material resonant infrared thermal detector and array

Xia Zhang, Communication Univ. of China (China); Dacheng Zhang, Peking Univ. (China)

Infrared (IR) sensors have been widely used for security systems, medical diagnosis, environmental pollution and climate changes analysis and others. IR sensors are classified into two types, photodetectors and thermal detectors. In comparison with photodetectors, thermal detectors are disadvantages in terms of sensitivity, response, thermal noises, etc. However, thermal detectors may also have the advantage of being capable of operating even at room temperature in which absorbed IR radiation on the sensing element is converted to heat and yields temperature change, not requiring a cooling system. Without a cooling system, the IR image system using an uncooled IR focal plane array (FPA), which is a thermal detector, has low power consumption, small size and low cost, and is a fast developing field.

An uncooled IR FPA based on microelectronics technology is a key component in the uncooled IR image system. Various uncooled FPAs such as bolometers, pyroelectric detectors, thermopiles, thermocouples, optical readout detectors etc., have been reported. Even though the infrared image systems using uncooled IR FPAs as detectors have advantages on power consumption, size and cost, the defects in their performance still exist. For example, bolometers depending on thermistor use direct current to sample a signal, resulting that their sensitivity decreases due to their sensing element temperature increasing; pyroelectric detectors need choppers to get static object images, making the image system using them complex; optical readout detectors are very sensitive to mechanical vibration, leading to the increase in their noise. Considering that resonant sensors may offer a high performance to many sensing applications such as pressure, acceleration and rotation sensors, whose sample current is smaller, thermal noise is lower, sensitivity is higher and resonant frequency yield is quasi-digital, a resonant IR thermal sensor with high sensitivity, whose sensing element is a bi-material structure with thermal expansion mismatch effect, is proposed in this paper. The resonant IR thermal sensors detect IR radiation by tracking the change in resonant frequency of sensing elements with temperature change attributed to the infrared radiation from targets. The bi-material structure can amplify the change in resonant frequency compared to single material sensing element. According to theory of vibration mechanics and design principle of thermal IR detector, a bi-material resonant IR sensor by which an array can be realized is designed. The relationship between the thicknesses of two materials and the change in resonant frequency of sensing elements with temperature change is analyzed. By ANSYS simulation analysis based on multi-layer shell finite element and optimized design, a bi-material thermal sensing structure has the dependence of resonance frequency on temperature of 1Hz/10mK. A resonant IR sensor array has successfully fabricated based on microelectronics technique being compatible with integrated circuit processes. With help of alternating current voltage driving the resonant IR sensor, the frequency variation corresponding to the temperature shift is obtained by electrical measurement.

9248-13, Session 4

Simple fiber optic sensor for applications in security systems

Marek Zyczkowski, Mateusz Karol, Piotr Markowski, Marta Napierala, Military Univ. of Technology (Poland)

In this paper we demonstrate measurement results of the modalmetric fiber optic sensor used to the monitoring of the fiber optic link integrity to protect it against unauthorized access to classified information. The presented construction is based on the detection of changes in the distribution of

modes in a multimode fiber. Any mechanical stress on the multimode fiber causes changes in polarization and distribution of propagating modes and hence it changes the distribution of modes at the end of multimode fiber. Observation these changes using a narrow core single-mode fiber allows the use of the structure as an optical fiber sensor.

We used several kilometers long optical links to conduct field tests of laboratory sensor. On this basis we also created the modalmetric fiber optic sensor in a version of the prototype module.

The modification of optoelectronic part, the variation of sensor length and the change of the method of light reflection at the fiber end enable the use of the modalmetric fiber optic sensor in many applications. It finds wide range of applications in security systems. It is used among other to protect the museum's collection, transmission lines and to protect critical infrastructure.

9248-14, Session 4

Improvement of optical and acoustical technologies for the protection: project IMOTEP. Network of heterogeneous sensor types for the protection of camps or mobile troups

Sébastien Hengy, Martin Laurenzis, Institut Franco-Allemand de Recherches de Saint-Louis (France); Veronique Zimpfer, Armin Schneider, ISL (France) and Inst Franco-Allemand de Recherches de Saint-Louis (France)

Snipers have emerged as a major threat to troops in recent conflicts. To reduce this menace, the objective of the research institute of Saint Louis (ISL) research project "IMOTEP" (improvement of optical and acoustical technologies for protection) is to improve the detection of snipers on the battlefield. Our basic approach is to combine several sources of information for a fast and appropriate reaction when an unusual signal (e.g. a flash or a shot) is detected. The project includes several technologies developed at ISL: acoustical detection, fusion of distributed sensor network data, active imaging and 3D audio communication.

The protection of camps, convoys or dismounted soldiers rests on a distributed acoustical sensor network that detects and localizes sniper attacks. An early estimation of the threat position is transmitted through a network to an active imaging system in order to confirm and refine this position by 3D imaging. The refined position is then sent to the control center which generates an alert message that displays the threat position using two formats: a tactical map and a 3D audio signal. In addition, the camp is protected by an adhoc sensor network used for intruder detection.

This paper presents the results obtained for the various technologies involved in the project IMOTEP.

The early detection system is a network of various types of acoustical shooter-detection sensors. Each of these sends only two types of information: the position of the node and the time of arrival of the Mach and muzzle waves. The network gives the shooter's position with a mean error of less than 2% with respect to the shooter-to-array distance , and an instananeous error of less than 10% for more than 90% of the shots, at distances ranging from 50 m to more than 1 km. The data fusion is still effective in an urban environment when the nodes are along the trajectory, whereas reflections can lure isolated sensors.

The active imaging sensor is a laser gated viewing system operating in the eye-safe shortwave infra-red band which can identify the threat and provide its precise location. The system is based on a water-cooled solid-state laser and an EBCMOS imaging sensor. The sensor unit and the laser illuminator are equipped with 10x zoom optics to handle wide and narrow fields-of-view with a perfectly matched illumination field.

3D audio communication uses the natural sense of the soldier for localizing sounds to draw his/her attention in the direction of the sniper. A warning signal whose origin is perceived as being in the direction of the sniper is presented via the headset of the soldier. This representation, called 3D audio display, provides an intuitive perception of the sniper's location without distracting the soldier. This method also can be used to allow enhanced communication between the soldiers. It is possible to process speech signals in a way that the location of the talker is spatially represented. This permits the listener to have an idea about the place where other members of the group are.

9248-27, Session PS

Analysis on polarization aberration of the coherent laser communication optical system

Yuan Hu, Changchun Univ. of Science and Technology (China) and Beijing Institute of Technology (China); Dewen Cheng, Beijing Institute of Technology (China); Lun Jiang, Changchun Univ. of Science and Technology (China)

Coherence is an important direction of future space laser communication technology development, but the implementation process is very difficult, one of question is heterodyne efficiency very sensitive to the uniformity of local wavefront and signal wavefront. Typical space laser communication optical system include mirror and transmission lens, spherical and aspheric surface, prism and flat, rotationally symmetric and off-axis surface, extremely complex. When the polarization beam through the optical system, because different incident angle cause by the different position, wavefront polarization state changes, thus affecting the heterodyne efficiency.

In this paper, based on the polarization aberration theory, the calculate method to the polarization aberration of typical optical elements are presented, the polarization aberration mathematical model of typical space laser communication optical system is deduced and analyzed. The results show that, the wavefront polarization state changes in space laser communication optical system can't be ignored in the application and implementation of coherence technique. And the coating or compensation way should be taken for improve the heterodyne efficiency

9248-29, Session PS

Coastal sensors for monitoring impacts of significant events on marine life

Aldo Bargnesi, Naval Undersea Warfare Ctr. (United States); Edward M. Carapezza, EMC, Inc. (United States)

No Abstract Available

9248-6, Session 5

Inference of vessel intent and behaviour for maritime security operations

Bert Broek, TNO Defence, Security and Safety (Netherlands)

Coastguard as well as military maritime assets are increasingly involved in Maritime Security Operations (MSO) for countering piracy, weapons and drugs smuggling, terrorism and illegal immigration. Persistent tracking of vessels in interrupted time series over long distances and the modeling of intent and behaviour from multiple data sources are key enablers for MSO. Results are presented for AIS/VTS observations in the Dutch North Sea and for simulated scenarios in the Gulf of Oman.

9248-30, Session 5

Towards a distributed implementation of the PHD-filter

Joris Sijs, Leon J. H. M. Kester, TNO Defence, Security and Safety (Netherlands)

Multi-Target Tracking in large-scale areas is dominated by distributed tracking solutions where the entire networked system consists of locally deployed sensor nodes. Each node performs measurements in its local surroundings to detect nearby objects. The resulting local detections are then associated into local tracks, possible using a multiple hypothesis approach. After that, the estimated tracks from the considered node are fused with estimated tracks from neighboring nodes, thereby retrieving a more accurate map of locally tracked objects. Multiple hypothesis tracking poorly scales with the number of objects to be tracked and suffers from fragility.

These drawbacks can be solved by using a PHD-filter for the considered tracking task. However, in order to fuse the results of neighboring nodes via distributed fusion solutions as Covariance Intersection (or its generalized form), the density maps resulting from a node's local PHD-filter should cover the entire area observed. This paper presents a preliminary study towards a more efficient implementation for distributed PHD-filtering: each node is allowed to compute a density map covering its own local surroundings, while fusion is done on the overlapping parts with other density maps computed by neighboring nodes.

9248-31, Session 5

Range measurements to improve navigation in a group of unattended vehicles

A. P. M. Maas, Danny J. Maat, TNO Defence, Security and Safety (Netherlands)

Research was conducted on groups of unattended vehicles performing some collaborative tasks. Navigation of these vehicles and more specifically, knowing each other's position, is mandatory. In densely built environments, forests etc., GPS is not always available or accurate. Using information about distances between the vehicles significantly improves position information. TNO developed the ARTS technology (Active Range Responder System) to do just that. ARTS also provides a means for communicating this position information between the vehicles.

9248-32, Session 5

Aerial Networking Communication solutions using Micro Air Vehicle (MAV)

Shyam Balasubramanian, Maurits de Graaf, Gerard Hoekstra, Thales Nederland (Netherlands); Henk Corporaal, Mark Wijtvliet, Technical University Eindhoven (Netherlands); Javier Cuadros Linde, Thales Nederland (Netherlands)

The multicopter acts as a mobile node in the mesh network, amongst other (static) nodes, using Disruption Tolerant Networking and Ad Hoc Networking to tackle communication disruptions and provide network extensions. The mobile node discovers other nodes while flying past several waypoints using GPS. The protocol was developed for automatic data transfer when a node becomes visible. Data may be files or real-time video, exchanged "on the fly". A proof of concept demonstration has been carried out; the development was in the context of the COMMIT Sensafety project, among others.

9248-33, Session 5

Encounter detection to improve navigation in a group of unattended vehicles *(Invited Paper)*

Marcel G. A. Ruizenaar, TNO Defence, Security and Safety (Netherlands)

Research was conducted on groups of unattended vehicles performing some collaborative tasks. Navigation of these vehicles and more specifically, knowing each other's position, is mandatory. In densely built environments, forests, etc., GPS is not always available or accurate. Using information about encounters between the vehicles significantly improves position information. Detecting encounters can be done very easily with low cost sensors. TNO developed a technology that uses information on encounters to improve the position information.

9248-11, Session 6

All-digital radar architecture

Pavlo A. Molchanov, Compass Systems Inc. (United States)

All digital radar architecture requires exclude mechanical scan system. The phase antenna array is necessarily large and cannot be all digital because the array elements must be co-located with very precise dimensions and will need high accuracy phase processing system for aggregate and distribute T/R modules data to/from antenna elements. Even phase array cannot provide wide field of view and need scan system.

New nature inspired all digital radar architecture proposed. The fly's eye consists of multiple angularly spaced sensors giving the fly the wide-area visual coverage it needs simultaneously to detect and avoid the threats around him. Fly eye radar antenna array consist multiple directional antennas loose distributed along perimeter of ground vehicle or aircraft and coupled with receiving/transmitting front end modules connected by digital interface to central processor. Non-steering antenna array cover entire sky by multiple overlap beams, excludes heavy mechanical scan system and/or power hungry phase processor and allows to create all-digital radar with extreme flexible architecture.

Fly eye radar architecture provides wide possibility of digital modulation and different waveform generation. Simultaneous correlation and integration of thousands signals per second from each point of surveillance area allows not only detecting of low level signals (low profile targets), but help to recognize and classify signals (targets) by using diversity signals, polarization modulation and intelligent processing. Array of multi-band or wide frequency directional antennas provides simultaneous multi-function work and as result better communication possibility than any regular scanning phase array.

Proposed all digital radar architecture with distributed directional antenna array can provide a 3D space vector to the jammer and spoofer by verification direction of arrival (DOA) for signals sources and as result simultaneous 360 degree azimuth and elevation jam/spoof protection not only for radar systems, but for communication systems and any navigation constellation system, for both encrypted or unencrypted signals, for not limited number or close positioned jammers.

Turning OFF one directional antenna provides 20-30 dB "nulling" for not limited number or close positioned hostile interference sources in antenna field of view (FOV) and 60-90 dB digital protection by verification of signals source position.

Directional antenna array is not as vulnerable as phase array. Antenna elements can be separated from signal processor by optical interface and damage of one or few elements will not damage all system. The directional antennas have higher gain, can be multi-frequency and connected to a multi-functional network. Distribution of space insulated antenna elements by aircraft perimeter provides "green" (no electromagnetic

irradiation) no interference zone inside ground vehicle or aircraft.

Fly eye micro-radars are inexpensive, can be expendable and will reduce cost of defense.

9248-12, Session 6

Independent motion detection with a rival penalized adaptive particle filter

Stefan Becker, Wolfgang Hübner, Michael Arens, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

Aggregation of pixel based motion detection into regions of interest, which include views of single moving objects in a scene is an essential pre-processing step in many vision systems and is able to support high level image analysis. When applied to static cameras, background subtraction methods achieve good results. On the other hand, motion aggregation on freely moving cameras is still a widely unsolved problem. The image flow, measured on a freely moving camera is the result from two major motion types. First the ego-motion of the camera and second object motion, that is independent from the camera motion. When capturing a scene with a camera these two motion types are adverse blended together.

In this paper, we propose an approach to detect multiple moving objects from a mobile monocular camera system in an outdoor environment. The overall processing pipeline consists of a fast ego-motion compensation algorithm in the preprocessing stage. Real-time performance is achieved by using a sparse optical flow algorithm as an initial processing stage and a densely applied probabilistic filter in the post-processing stage. Thereby, we follow the idea proposed by Jung and Sukhatme. Normalized intensity differences originating from a sequence of ego-motion compensated difference images represent the probability of moving objects. Noise and registration artefacts are filtered out, using a Bayesian formulation. The resulting a posteriori distribution is located on image regions, showing strong amplitudes in the difference image which are in accordance with the motion prediction. In order to effectively estimate the a posteriori distribution, a particle filter is used. An advantage of using a particle filter is its ability to capture multiple modes of the underlying distribution. Under the following conditions, this ability can ensure a multi target tracking with a single set of particles. On the one hand all objects should be present at the beginning of the estimation process and on the other hand particles should not converge too early onto a single target. Both conditions are not met in most scenarios. Not only the number of independent moving objects is unknown, further most particles are absorbed by the dominant motion and an equivalent amount of motion over time for all objects is not realistic. Especially when dealing with objects showing non-rigid motion patterns, such as the motion of a person, motion of a single object part can dominate the particle filters convergence. As a consequence, the particles are not homogeneously distributed over the objects surface.

In addition to the fast ego-motion compensation, the main contribution of this paper is an insight into the design of the probabilistic filter for real-time detection and tracking of independently moving objects. The proposed approach adapts a particle filter in order to rapidly detect objects entering a scene. The proposed approach introduces a completion scheme between particles in order to ensure an improved multi-modality and an improved particle distribution over targets showing non-rigid motion patterns. The effectiveness of the method is shown across a range of prototypically outdoor sequences.

9248-15, Session 6

PADF electromagnetic source localization using extremum seeking control

Huthaifa A. Al Issa, Univ. of Dayton (United States) and Jerash Univ. (Jordan); Raúl Ordóñez, Univ. of Dayton (United States)

Wireless Sensor Networks (WSNs) are being used in a variety of ways: from reconnaissance and detection in military to biomedical applications toward environmental sensing applications and a variety of commercial endeavors. In recent years, position-based services have become more important. Thus, recent developments in communications and RF technology have enabled system concept formulations and designs for low-cost radar systems using state-of-the-art software radio modules, which are capable of local processing and wireless communication, a reality. Such nodes are called as sensor nodes.

Most wireless sensor network applications require knowing or measuring locations of thousands of sensors accurately. For example, sensing data without knowing the sensor location is often meaningless. Locations of sensor nodes are fundamental to providing location stamps, locating and tracking objects, forming clusters, and facilitating routing,

This research focused on the modeling and implementation of distributed, mobile radar sensor networks. In particular, we worked on the problem of Position-Adaptive Direction Finding (PADF), to determine the location of a non- collaborative transmitter, possibly hidden within a structure, by using a team of cooperative intelligent sensor networks. Position-Adaptive radar concepts have been formulated and investigated at the Air Force Research Laboratory (AFRL) within the past few years. We present the experimental performance analysis on the application aspect. We apply Extremum Seeking Control (ESC) schemes by using the swarm seeking problem, where the goal is to design a control law for each individual sensor that can minimize the error metric by adapting the sensor positions in real-time, thereby minimizing the unknown estimation error. As a result we achieved source seeking and collision avoidance of the entire group of the sensor positions.

9248-16, Session 6

Coordinating UAV information for executing national security-oriented collaboration

Anthony W. Isenor, Defence Research and Development Canada, Atlantic (Canada); Yannick Allard, OODA Technologies Inc. (Canada); Anna-Liesa S. Lapinski, Defence Research and Development Canada, Atlantic (Canada); Hugues Demers, Dan Radulescu, OODA Technologies Inc. (Canada)

Unmanned Aerial Vehicles (UAVs) are being used by numerous nations for defence related missions. In some cases, the UAV is considered a cost-effective means to acquire data such as imagery, over a location or object. Considering Canada's geographic expanse, UAVs are also being suggested as a potential platform for use in surveillance of remote areas, such as the Canadian north. However, such activities are typically associated with security as opposed to defence. The use of a defence platform for security activities introduces the issue of information exchange between the defence and security communities and their software applications.

This paper explores the flow of information from the system used by the UAVs employed by the Royal Canadian Navy. Multiple computers are setup, each with the information system used by the UAV. Video data from a maritime UAV mission are then transferred to information system one, which is synchronized with system two using an adjustable bandwidth router. These conditions mimic the collection of UAV video data

on a ship that controls the flight of the UAV, and subsequent transfer of the data to a second ship or unit. Simulated Automatic Identification System (AIS) data is also included as part of the data collected by the UAV platform. The simulated AIS is also fed into information system one and subsequently synchronized with system two.

To store and transfer the simulated AIS data within the UAV information system, we utilize a second information structure common to the Canadian security community. The second structure is from the National Information Exchange Mechanism (NIEM), an open-source community-developed exchange model. The NIEM structure is encapsulated within a UAV information message to utilize the synchronization between UAV systems. After synchronization, the content of the NIEM message is displayed using two open source geospatial applications, the Quantum Geographic Information System (QGIS) and the NASA World Wind virtual globe. Use of NIEM information structures and applications relevant to the security community avoids the distribution restrictions often associated with defence-specific applications.

Results of the investigation indicate limitations regarding the inclusion of AIS data within the UAV information system. This is in part due to the UAV system being better structured to store information products, versus data that would be used to generate a product. This difference also slows data retrieval for the purpose of visualization, in both QGIS and NASA World Wind. This work helps illustrate the importance of information science issues related to the sharing and exploitation of information across the defence and security communities.

9248-17, Session 6

Implementing the distributed consensus-based estimation of environmental variables in unattended wireless sensor networks

Rodrigo Contreras, Silvia E. Restrepo, Jorge E. Pezoa Nunez, Univ. de Concepción (Chile)

Unattended Wireless Sensor Networks (WSNs) have enabled the environmental monitoring of remote and harsh scenarios. Unattended WSNs are large, clustered networks that must adapt to network and environment dynamics in order to autonomously operate during long periods of time. Due to the limited storing resources of the sensor nodes, in-network processing must be conducted by the WSN. The calculation of the average value of the sensed variables is a typical in-network processing operation. Distributed consensus algorithms have been developed to compute the global average value of the measured environmental variables. Distributed consensus algorithms perform the calculation, in a recursive fashion, by properly weighing and locally exchanging estimates of the global values at each sensor node. In practice, however, distributed consensus algorithms must deal with two major issues: (i) the random topological changes of the network; and (ii) the time to reach consensus is finite.

In this paper, the prototype implementation of a scalable, distributed protocol for calculating the global average of sensed environmental variables in unattended WSNs is presented. The proposed protocol deals with the two aforementioned issues as follows. First, the design and implementation of the protocol introduces a communication scheme for discovering the WSN topology. Such scheme uses a synchronous flooding algorithm, which was implemented over an unreliable radiogram-based wireless channel. The topology discovery protocol has been synchronized with sampling time of the WSN and must be executed before the consensus-based estimation of the global averages. Second, an average consensus algorithm, suited for clustered WSNs with static topologies, was selected from the literature. The algorithm was properly modified so that its implementation guarantees that the convergence time is bounded and less than the sampling time of the WSN. Moreover, to implement the consensus algorithm, a reliable packet-passing protocol was designed to exchange the weighting factors among the sensor nodes. Since the amount of data exchanged in each packet is bounded by the degree of the WSN, the scalability of the protocol is guaranteed to be linear. The proposed protocol was implemented in the Sun SPOT hardware/software platform using the Java programming language. All the radio communications were implemented over the IEEE 802.15.4 standard and the sensed environmental variables corresponded to the temperature and luminosity. The statistical analysis of the execution and communication times of the implementation showed that the longest times correspond to the exchange of messages associated to the consensus algorithm. Moreover, the largest energy consumption at each node occurs during the exchange of such data.

9248-18, Session 6

Detection of people in military and security context imagery

Thomas M. Shannon, Ben Wiltshire, Emmet H. Spier, 2d3 Sensing (United Kingdom)

The traditional use of aerial platforms for intelligence gathering is greatly challenged by the nature of cluttered and congested urban operating environments and restricted lines of sight. It is likely that ground based acquisition systems will become more prevalent in future urban operations with exploitation drawn from new and emerging electro-optic surveillance technologies. Recent and current operations in Northern Ireland, Iraq and Afghanistan undertaken by British forces and in Somalia by US troops are examples that have clearly demonstrated that for ground forces to fight effectively in built-up areas, or to act as aids to the civil power, they must first have access to current and pertinent intelligence about the existing and likely threats they face.

A high level of visual surveillance implies a heavy human work-load unless the presence of threats can be automated. Automated surveillance systems must first be capable of robustly detecting individuals who may pose a potential threat within complex scenes. Our research addresses this challenge by considering the presence of persons who may be partially obscured by structures, by handling personal infantry weapons or by the tactical pose they have adopted. We applied current computer vision techniques to achieve reliable detections within two dimensional images by investigating a recently published approach based on the construction of cascaded non-linear classifiers from part-based deformable models. Performance was quantified by assessing how well the method detected subjects handling weapons in common operational use when tasked to undertake low level infantry tactics in the open and when obscured together with innocent civilian activities. Results were compared with published literature where the same method was applied to publically available upright pedestrian imagery.

Earlier research based on feature descriptors such as the histograms of oriented gradients (HOG) trained using the support vector machine approach has shown that although this method is robust in detecting humans in images of limited quality, it fails in cases where the human subject is partially occluded or overlaps another subject. We address these shortcomings by revisiting the problem based on recently published work that focussed on the detection and association of object parts. Bounding the location of people in a scene then opens the opportunity to apply emerging two dimensional pose classification algorithms to attempt to identify both the likely activity and the possible intent. Our findings are that the new method has the potential to become a useful people detection tool, yielding a precision of approximately 70% for a recall rate of around 85% when applied to our military context imagery.

Identifying potential local threats remains hugely challenging for the soldier on the ground that is further exacerbated in those operations where enemy combatants do not wear any identifying uniforms and may blend in with, or are part of, a

local civilian population. Applying near real-time computer vision techniques to detecting individuals who may have hostile intent and pose an imminent threat could be of significant value.

9248-34, Session 6

Adaptive multi-sensor biomimetics for unsupervised submarine hunt (AMBUSH): Early results

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Underwater surveillance is an inherently difficult problem because acoustic wave propagation and transmission are limited and unpredictable when moving targets and sensors move around in the communication-opaque undersea environment. Today's Navy underwater sensors enable the collection of a massive amount of data, often analyzed offline. The Navy of tomorrow will dominate by making sense of that data in real-time. DRDC's AMBUSH project proposes a new undersea-surveillance network paradigm that will enable such a real-time operation.

This publication describes a year's worth of research efforts related to the AMBUSH project, which finds inspiration in Nature's collaborative tasks such as wolves hunting in packs, to advance undersea-surveillance. Indeed, Nature abounds with examples of collaborative tasks taking place despite limited communication and computational capabilities. Moreover, behaviour found in nature often is robust to severe disturbances just like flocks of migrating birds maintaining the v-shape formation despite the fact that a hunter may have taken down the leading bird.

The AMBUSH project proposes the utilization of a heterogeneous network combining both static and mobile network nodes. The military objective of this project is to enable an unsupervised surveillance capability while maximizing target localization performance and endurance. The main scientific objective is to develop the necessary technology to acoustically and passively localize a noise-source of interest in shallow waters. The project will fulfill these objectives via distributed computing while exploiting the changing undersea environment to its advantage. Other direct benefits of this research project are the reduction of submarine threat exposure, an increase in sensors' coverage, and an acceleration of the first two stages of the observe-orient-decide-act (OODA) loop.

Specific research interests discussed in this paper relate to distributed-computing and adaptation schemes for performing: (a) network self-discovery, (b) network connectivity self-assessment, (c) opportunistic network routing, and (d) distributed data-aggregation. We briefly review the latest results and challenges facing those four research areas. For network self-discovery, a scheme for estimating dynamic changes in network composition and size is reviewed. A network connectivity metric handling extreme cases when the network behaves like a random graph is also presented. A location-free network routing technique is introduced and early results are discussed. Distributed data-aggregation techniques are reviewed and compared against a real underwater acoustic dataset. For each of those research fields, current trade-offs and limitations are discussed. Wherever appropriate, references to already published results will be provided. Experimental plans to test the above techniques are presented along with the experimental gear and locations. Results from past trials will also be briefly discussed. This publication concludes by outlying future tasks being undertaken.

9248-19, Session 7

DAZZLE project: UAV to ground communication system using a laser and a modulated retro-reflector *(Invited Paper)*

Yoann P. Thueux, Nicholas Avlonitis, Gavin R Erry, Airbus Group (United Kingdom)

The advent of the Unmanned Aerial Vehicle (UAV) has generated the need for reduced size, weight and power (SWaP) requirements for communications systems with a high data rate, enhanced security and quality of service. This paper presents the current results of the DAZZLE project run by Airbus Group Innovations in Newport, Wales. Here, we detail the specifications, integration steps and performance of a UAV to ground communication system using a laser and a modulated retro-reflector. The laser operates at the wavelength of 1550nm and at a power level that guarantees eye safety. It is pointed using a FLIR pan and tilt unit driven by an image processing-based system that tracks the UAV in flight at a range of a few kilometers. The modulated retro-reflector is capable of a data rate of 20Mbps over short distances, using 200 mW of electrical power. The communication system was tested at Pershore airfield in late 2013. Video data from a flying Octocopter was successfully transmitted over 1200m. During the next phase of the DAZZLE project, the team will attempt to produce a modulated retro-reflector capable of 1Gbps in partnership with the research institute ACREO based in Sweden. A high speed laser beam steering capability based on a Spatial Light Modulator will also be added to the system to improve beam pointing accuracy.

9248-20, Session 7

Channel Modelling for Free-Space Optical Inter-HAP Links Using Adaptive ARQ Transmission

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Free-space optical (FSO) communication systems have seen significant developments in recent years due to growing need for very high data rates and tap-proof communication. The operation of an FSO link is suited to diverse variety of applications such as satellites, High Altitude Platforms (HAPs), Unmanned Aerial Vehicles (UAVs), aircrafts, ground stations and other areas involving both civil and military situations. FSO systems have significant advantages compared to conventional RF systems - overcoming interference, bandwidth exhaustion, providing higher data rates in multi-gigabit regime.

However, significant challenges arise in FSO communication systems due to different effects of the atmospheric channel. FSO channel primarily suffers from scintillation effects due to Index of Refraction Turbulence (IRT). In addition, acquisition and pointing becomes more difficult because of the high directivity of the transmitted beam: Miss-pointing of the transmitted beam and tracking errors at the receiver generate additional fading of the optical signal. The resulting loss at the receiver is eventually weakening the overall performance of the communication system.

Automatic Repeat reQuest (ARQ) schemes are often preferred as Error Control technique for communication systems with higher data rates to improve the impairments of the channel. A vital factor determining the ARQ scheme design is the fading characteristics of the channel. In order to propose a suitable ARQ scheme for a FSO communication link, proper theoretical understanding of the optical atmospheric propagation and modeling of a specific scenario FSO channel is required. As the fading behavior is unique to each optical channel, a specific scenario has to be considered to model the optical channel.

High Altitude Platforms (HAPs) are quasi-stationary vehicles operating in the stratosphere. The slowly varying but precisely determined time-of-flight of the Inter-HAP channel adds to its characteristics. An ARQ scheme cannot be designed generic to all FSO applications. Rather, it has to be tailored for each specific atmospheric channel or scenario. The proposed methodology therefore provides an efficient way to choose an ARQ scheme based on the fading statistics and the Bit Error Rate (BER) characteristics of simulated FSO Inter-HAP channel model.

In this paper, a bi-directional symmetrical Inter-HAP link has been selected and modeled. The Inter-HAP channel model is then investigated via simulations in terms of optical scintillation induced due to IRT, beam miss-pointing and tracking errors at the receiver. The performance characteristic of the model is then quantified in terms of fading statistics from which then the BER is calculated. Based on the BER characteristics, we are then able to propose suitable ARQ schemes.

The presented approach can be employed considering channel reciprocity in Inter-HAP link into consideration meaning the received signal levels at both link ends are similar or, ideally, identical. This approach can also be further extended to choose an appropriate Forward Error Correction (FEC) scheme as a part of error correction technique. This leads to an option of designing a hybrid error detection and correction system.

9248-21, Session 7

Demonstration of high-rate laser communications from fast airborne platform: flight campaign and results

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Some current and future airborne payloads like high resolution cameras and radar systems need high channel capacity to transmit their data from air to ground in near real-time. Especially in reconnaissance and surveillance missions, it is important to downlink huge data during very short contact times to a ground station during a flyby. Aeronautical laser communications can supply the necessary high data rates for this purpose. Within the project DODfast (Demonstration of Optical Data link fast) a laser link from a fast flying platform was demonstrated. The flight platform was a Panavia Tornado with the laser communication terminal installed in an attached avionic demonstrator pod. The air interface was a small glass dome protecting the beam steering assembly. All other elements were integrated in a small box inside the Pod's fuselage. The receiver station was DLR's Transportable Optical Ground Station equipped with a free-space receiver front-end. Downlink wavelength for communication and uplink wavelength for beacon laser were chosen from the C-band-DWDM grid. The test flights were carried out at the end of November 2013 near the Airbus Defence and Space location in Manching, Germany. The campaign successfully demonstrated the maturity and readiness of laser communication with a data-rate of 1.25 Gbit/s for aircraft downlinks. Pointing, acquisition and tracking performance of the airborne terminal and the ground station could be measured at aircraft speed up to 0.7 Mach and video data from an onboard camera has been transmitted. In this paper, we describe the system architecture, the flight campaign and the results.

9248-22, Session 7

Novel non-mechanical fine tracking module for retroreflective free space optics

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The unmanned aerial vehicle (UAV) industry has urgent requirements for high-bandwidth wireless communications to allow fast offloading of video streaming or sensor data to a ground base station (BS). Free space optical communications (FSO) technology provides an attractive alternative to RF technologies, as it offers point to point data links, potentially at high data rates (e.g. Gbit/s). Optical links are immune to interception or jamming, require no spectrum licensing and can be achieved with eye-safe, low-power and lightweight components.

Retroreflective free space optical (RFSO) communications is a promising technology which employs a modulator retro-reflector (MRR) to modulate and reflect back a CW interrogator beam launched from a BS. This architecture highly simplifies the UAV transceiver, reducing both weight and power consumption. A high precision pointing and tracking module is required on the BS. To achieve this, we have designed a two-step tracking system. First, a coarse tracking module uses a visible camera and a Vilga video tracker board to control a Pan Tilt Unit (PTU). Secondly, a non-mechanical fine tracking function is performed by a holographic beam steering unit. The beam steering is applied based on an angle of arrival sensor (an InGaAs camera).

Holographic beamsteering is executed using a Spatial Light Modulator (SLM). A phase-only mode SLM is a planar pixelated device where each pixel independently controls the phase of an incident beam wavefront. In this system we make use of both the beamsteering capabilities of the SLM, and also its adaptive optics potential.

In this paper, we report system details and preliminary results from fine tracking field tests.

9248-23, Session 7

Assessment of laser tracking and data transfer for underwater optical communications

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No Abstract Available

9248-24, Session 7

In-door artificial atmospheric beamlet as a test-bed for adaptive optics

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The unique indoor atmospheric beamlet in Sosnovy Bor (Leningrad region, 80 km from St.-Petersburg) is comprised by 15 high (diffraction limited) quality 300 mm plane mirrors (HR coated for 0.53 and 1.06 micron). The maximal length of free space propagation along this beamlet is 700 m. The beamlet is placed in the capsulated compartment, placed inside the building, providing high stability and reproducibility of atmospheric conditions inside. The compartment is equipped by heaters and fans, which can provide the controlled and repeatable distortions of atmosphere inside. This test-bed provides the unique capabilities for testing various optical systems. In the past it was successfully used for various laser beam propagation studies and nonlinear-optical compensation.

In our talk we present the first results of investigations of implementation of the closed-loop adaptive optical system at the beamlet segment with the length 80-240 m. We have used the standard system of NightN Co. production (http://www.nightn.ru/files/products/files/adsys/adsys.htm), providing correction of not too fast (not more than 30 Hz) distortions. It was shown that under stable conditions (without heating and artificial wind) the distortions, accumulated along the path, have the magnitude of 1-2 microns (peak-to-value) and are rather slow. The use of closed-loop adaptive optical compensation in a single-mirror (flexible mirror diameter 50 mm; no tip-tilt correction) provided complete correction of these distortions down to diffraction limited performance. So our first experiments has confirmed the expectations that out beamlet can be used in future as a rather convenient test-bed for various adaptive optical systems' investigations and characterization with the rather "soft" starting conditions.

9248-25, Session 7

Modulation techniques used in earth to satellite and inter-satellite free space optical links

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Modulation techniques used in terrestrial and inter-satellite free space optical communications have been well researched in the past decade. But the performance analysis of modulation schemes used in earth to satellite uplink/ downlink is hardly found in literature. A few research papers give the performance of some intensity modulation schemes for optical satellite links in weak atmospheric turbulence employing the log-normal model for atmospheric turbulence. It has been found that the gamma-gamma model is more accurate in weak turbulence than the log-normal model. Also, it is valid for moderate to strong turbulence levels also, making analysis and comparison for a wide range of turbulence conditions easier. However, owing to the complexity of the analysis, no closed form solutions for the bit error rate analysis for satellite communications has been found.

The turbulence for a vertical/slant optical satellite link mostly falls in the weak regime for zenith angles less than 60 degrees. But for large zenith angles, the turbulence quickly falls into the moderate and strong regime. Also, the off axis scintillation increases rapidly for an optical satellite uplink. Hence there is a need for analysis of the performance of modulation schemes in the moderate and strong turbulence levels as well.

Pulse modulation schemes such as Pulse Position Modulation(PPM), Differential Pulse Position Modulation(DPPM), Pulse Amplitude and Position Modulation (PAPM) and Differential Amplitude Pulse Position Modulation(DAPPM) have been considered for analysis in this paper. PPM has been well researched for its superior power efficiency for long distance free space optical communications. It performs well for inter-satellite links where there is no atmospheric turbulence. But its high bandwidth requirement limits its use in the presence of turbulence which causes pulse spreading and degradation in performance. Also, for satellite uplink and downlink, the presence of weather conditions such as fog, rain, haze or clouds cause multiple scattering which further spreads the pulse. The effect of these multiple scattering effects on the spreading of the pulse is also studied. Due to this, more bandwidth efficient schemes would be preferable for the uplink and downlink.

DPPM has the advantage of inherent symbol synchronization capability as compared to PPM which requires both symbol and slot synchronization, the errors in which could degrade the performance considerably. Hence, this reduces the complexity of the receiver and is also more bandwidth efficient. PAPM and DAPPM are multiple amplitude versions of PPM and DAPPM, respectively. Because of their high capacity, they are also well researched. The performance of PAPM and DAPPM is worse than that of PPM and DPPM with the same average transmitted power owing to the reduction in spacing between amplitude levels. But their performance can be improved by using optimum threshold detection. This work will provide closed form solutions for the analysis of PPM, DPPM, PAPM and DAPPM for ground to satellite, satellite to ground and inter-satellite optical free space communications. Gamma-gamma turbulence model has been considered because of its accuracy and validity in a wide range of turbulence regimes.

9248-26, Session 7

Lower bound on number of telescopes in an optical array receiver for deep space optical communication

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Optical communications technology has the characteristics to provide a broadband communication support for the future missions launched for exploration of solar system in deep-space. Traditionally, telescopes are employed in astronomical applications for observations of celestial objects. However, in extremely long-distance free-space optical communication, such as interplanetary deep space optical communication, telescopes are employed as antennas both at the transmitter and receiver end. Keeping in view the constraints of telescope size at the transmitter of a spacecraft, a large aperture size telescope (i.e., ≈ 10 m) is needed at an earth-based receiver to support the acceptable data rates for free-space optical communication. However, it is a formidable task to fabricate and maintain a high-quality and extremely large diffraction-limited telescope. Comparatively, an array of smaller telescopes, electrically connected to form a bigger photon-collecting aperture is an attractive alternative to a large telescope for an optical receiver operating in a deep-space optical communication link.

In this paper, performance of an optical array receiver is evaluated for a free-space optical communication link between Earth and Mars, with an objective to find the lower bound on the number of telescopes that can be employed in an earth-based optical array receiver. Theoretically, an optical array receiver consisting of any number of telescopes would

perform equivalent to single large telescope, as long as the total photon-collecting aperture is same as that of the single telescope. The objective in this paper is to verify this premise in an actual operational scenario of a free-space optical communication link between Mars and Earth.

In the analysis, specifications of the transmitter, receiver, and other link budget parameters are chosen based upon the state-of-the-art, space-qualified technology. A 5W laser operating at 1.06 and a 30 cm telescope is selected at the transmitter of a spacecraft in Mars orbit. Photon-counting detectors with the capability of detection of single photon arrivals are assumed at the receiver end. Pulse-position modulation is employed for the communication link. The performances of different array architectures are evaluated using analytical techniques and Monte-Carlo simulations.

The analysis and results are presented for a wide range of operational conditions including the Mars-Earth opposition and Mars-Earth conjunction phase. Various limiting factors such as, background noise and atmospheric turbulence are also included in the simulations and analysis. The results are evaluated for different array architectures ranging from one telescope with 10 m aperture diameter to thousands of smaller telescopes in the array, with the equivalent total aperture diameter. The results show that during an actual operational scenario between Earth and Mars, performance of an array consisting of 100 telescopes with 1 m diameter is almost equivalent to a single telescope with 10 m aperture diameter. The performance loss of an array consisting 135 telescopes with 0.86 m is also minimal. However, if the telescopes diameters are reduced below 0.86 m, the performance degradation is substantial. Hence, it can be concluded that an optical array receiver can replace a monolithic 10 m telescope as long as the individual telescope diameter exceeds that of the 0.86 m. Additionally, it is further shown that compared to the current RF technology, a telescope array receiver can support the data rates of about 120 M bit/s during the Earth-Mars opposition phase and 13 M bits/s during the Earth-Mars conjunction phase.

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9249-1, Session 1

Method for increased detection range in IR warning systems

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In Infra-Red (IR) point target warning systems, the range is determined by the effective entrance pupil diameter of the system's optics. In addition, the system's F/# is usually set by the detector (as in cryogenically cooled detectors). Moreover, the detector's proportions usually set the field proportions (5:4, 4:3, etc.).Thus for example, for wide angle systems, the horizontal coverage angle is usually determining the vertical one.

Our invention is a system including anamorphic optics that changes the effective focal length of each axis independently, keeping the detector's given F/#, thus changing the effective aperture. Since the range is approximately proportional to the effective aperture, we achieve a range improvement of the square-root of the vertical and horizontal focal length ratio, reducing the vertical coverage accordingly. In this way we make the field proportions independent of the detector's proportions.

Using this method, it is made possible for wide angle systems to improve target detection range on the expense of the vertical coverage, and without changing the horizontal coverage or increasing the amount of detection units (e.g. FLIRs).

9249-2, Session 1

Simultaneous image stabilization and motor control in semi-stationary video applications

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Semi-stationary multi-camera components are designed to be easily mount- and demountable. Since it is not possible to make strong assumptions about the environment, where such components are applied, it is necessary for these components to be adaptable to their environment. Towards this end, we have proposed a setup consisting of a wide-angle overview camera (master camera) and a controllable PTZ camera (slave camera) in previous work. The setup consists of off-the-shelf hardware, where no assumptions about special hardware characteristics are made. This setup is able to automatically determine the configuration between both cameras.

In this paper we continue this previous work by addressing the problem of tracking objects in a dynamic environment by simultaneously integrating motor control and image stabilization. The overall task is to provide a stable close up view of a moving object, by dynamically adjusting the PTZ's viewing direction. Close-up views are important for human observers, as well as for automated video analysis components, which require a sufficient amount of resolution.

In order to fulfill this task several error sources have to be considered. First, our camera setup is affected by a small amount of ego-motion which is caused by wind or by vibrations originating from the PTZ motion, which can strongly affect the systems portable tripod. Second, no strong assumptions about the PTZs control mechanisms are made. Accelerations and speed of the PTZ control are mainly non-linear and therefore hard to predict. As a consequence, alignment between the PTZ motion and the object motion is a non-trivial control task.

Therefore, a cohesive approach is proposed, which integrates image stabilization, motion prediction, and motor control into a single control loop. The major focus of this work is to keep the system adaptable, i.e. that no special calibration method is required in order to get the system operable under unknown environmental conditions. The effectiveness of the proposed method is illustrated by generating close-up video snippets of moving people in realistic outdoor scenarios.

9249-3, Session 1

Modeling transient thermal behavior of shutterless microbolometer-based infrared cameras

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The present trend of miniaturizing infrared cameras derives from the wish to enter new fields of application, e.g. automotive devices, intelligent buildings or process controlling. This benefits from recent progress in the Microbolometer manufacture process which leads to smaller, higher integrated and particularly cheaper sensor arrays. Main goal are compact and robust radiometric infrared cameras consisting only of lens system, sensor array and digital signal processing unit, like already available infrared imager. Shutterless infrared cameras are nothing but the next evolutionary step in this direction after the development of TEC-less infrared cameras. However, the measurement uncertainty should be comparable to state of the art shutter-based Microbolometer infrared systems.

Nonetheless the problem of disturbing radiation derived from the interior of the camera stays the same for infrared cameras with and without temperature stabilization (TEC). The amount of internal radiation depends on the ambient temperature and the heat generation through electrical components used for digital signal processing. Variation of ambient temperature leads to a change of the temperature distribution inside the camera. Our approach is determining the disturbing radiation without using a shutter by measuring the internal thermal state with several temperature probes and deducing the disturbing radiation flux. Because of this discrete temperature measurement it is not possible to determine the present thermal state of the camera interior as precise as performing a shutter process. Therefore, the position of the temperature measurement is crucial for the significance of the relation between measured temperature and disturbing radiation flux. Furthermore the transient thermal behavior during a cooling or heating period of the camera enclosure is a non ergodic process [1]. That means not only the present thermal state of the camera has to be taken into account for calculating the disturbing radiation flux, but also the history of the thermal behavior. We analyze two approaches facing these problems.

We use more than one temperature probe at different positions inside the camera. Each position of temperature measurement has its own composition of heat conductance and convection parameters. Therefore the low pass behavior and the correspondent responds time of the measured temperature in relation to the ambient temperature differ. Developing a thermal model using different probes with a higher significance of the transient thermal trend reduces the calculation uncertainty.

A second approach is to separate the transient and the steady state behavior of the calculation model. If the change of ambient temperature is slow enough the thermal circumstance inside the camera follows this change completely. It stays always in steady state and the process is ergodic. In case of an abrupt change of ambient temperature the thermal behavior leaves the steady state and a transient correction factor is necessary. This factor has to take the history of the measured temperature into account. This is essential if the camera is

located in rough environment with often arbitrarily changing ambient temperature.

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9249-4, Session 1

Nondestructive testing of CFRP with small arms impacts by IR thermography methods

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Protecting the crew of vehicles is one of main priorities at upgrading the Polish Armed Forces. More and more high levels of crew protection appear in technical requirements on new military equipment (mailnly vehicles or their elements). In aim of satisfy of these requirements used newest solution of material engineering – light-weight ballistic covers.

The paper introduces a diagnostic technique making possible the research of internal structures in composite material (CFRP – carbon fiber reinforced plastic) that is used more often in construction of light armors protecting vehicles. Little mass and the resistance against the perforation with bullets and fragments are basic requirements of contemporary armors. This requirement could be met by using composites. Composite armor is examined by testing its ballistic resistance and this is performed by carrying out bullet proof tests. During this test in the moment of bullet’s striking into armor the composite material comes into destruction of its internal structure on a considerable area. This is especially visible in multi-layer composites. It causes so-called delamination which is characterized by the loss of interlayer cohesion and destruction of continuity of polymer matrix in which the fiber is embedded. Delamination appears both in the case of full and partial penetration of bullet. The composite material is practically destroyed in area of delamination. This is very difficult to evaluate the size of delamination area from outside because in most cases external symptoms of internal damage of composite structure are not visible. The delamination area may be well estimated by using methods of non-destructive testing. This method has to assure a high detection of defects and a high speed of inspection. These requirements may be met by IR thermography diagnostic methods. Comparison of testing of a composite sample (CFRP) by means of pure optical method and methods that use ultrasonic and eddy current stimulations as well as lock-in thermography method will be presented.

Comparative experimental investigations showed, that:

- thermography with eddy current stimulation gives non-satisfactory results of detection defects in CFRP.

- exist differences in dimensions of detected defects between Step Heating Thermography and ultrasonic thermography. The fact that optical (surface) and ultrasonic (volumic) stimulation produce very different ‘footprints’ of subsurface defects was indicated elsewhere [9]. A very simple explanation to this fact is that heat flux propagating from surface in-depth experiences the greater disturbance on thicker defects because of a greater defect thermal resistance. Oppositely, ultrasonic stimulation is more effective for thinner defects because of a more intensive friction. Therefore, optical stimulation exhibits big defects, while ultrasonic thermography might be good for the detection of small defects.

9249-5, Session 1

Optical fibre techniques for use within tamper indicating enclosures designed for arms control verification purposes

Thomas C. Dyer, Alexander W. J. Thompson, Paul Wynn, Helen White, AWE plc (United Kingdom)

The technical verification of a possible future nuclear arms control agreement is a complex challenge for technology developers. Chain of custody, in this context, is a connected series of procedures and technologies designed to account for treaty relevant items throughout the dismantlement process and provide confidence that the integrity and authenticity of an item has been maintained. Tamper indicating enclosures (TIEs) will likely be deployed as part of a chain of custody regime to indicate an unauthorised attempt to access a treaty accountable item, or to secure authenticated monitoring equipment. The focus of this paper is on the use of optical fibre techniques for maintaining boundary control as part of a TIE design. The paper considers the use of optical fibres from the perspective of deployment within a technical verification regime. An initial experimental survey of a number of fibre types was undertaken.

Of fundamental interest to this work is the ability of a given optical fibre construct to provide an optical signature which would either uniquely identify the TIE or highlight an unauthorised attempt to breach and then repair the boundary. It is also important to consider how the host and monitoring parties could obtain and maintain mutual trust in the deployed equipment. Each technique is therefore assessed with a view to the ultimate authentication/certifocation process, as well as assessing each approach from the perspective of field deployment.

This paper will present initial results from this survey and discuss potential avenues for future research into a final integrated TIE design. The optical responses of a range of optical fibre constructs under varying physical factors have been investigated. The physical parameters considered include bend radii, tension, torsion, physical damage and splicing. The reported work investigates single mode, multimode, polarization maintaining and spun (high and low birefringence) optical fibres. Optical measurements were made using a telecommunication wavelength (1550 nm) and visible wavelength sources. Characteristics of interest include changes to the transmission/reflectance spectra and changes to the polarization state of propagation. Consideration was also made regarding the effect of embedding fibres within diferent materials as well as the potential winding pattern for the enclosure. Authentication of boundary coverage was a key parameter to consider in this scenario and a simple

in-situ method for authenticating the path of the fibre through the TIE was validated for the selected fibre types.

Results show diferent optical responses to the given physical factors across the range of fibre constructs and operating conditions.

9249-6, Session 2

Passive athermalization of doublets in 8-13 micron waveband

Norbert Schuster, Umicore Electro-Optic Materials (Belgium)

Passive athermalization of lenses has become a key-technology for automotive and other outdoor applications using modern uncooled 25, 17 and 12 micron bolometer arrays. Thermal drift of index of refraction and the geometrical changes (in lenses and housing) versus temperature defocus the initial image plane from the detector plane. The passive athermalization restricts this trop of spatial resolution in a wide temperature range (typically -40oC...+80 oC) to an acceptable value without any additional external refocus.

In particular, lenses with long focal lengths and high apertures

claim athermalization. Lens arrangements containing two lenses (doublets) minimize costs. A careful choice of lens and housing materials and a sophistical dimensioning lead to three different principles of passivation: The Passive Mechanical Athermalization (PMA) shifts the complete lens cell, the Passive Optical and Mechanical Athermalization (POMA) shifts only one lens inside the housing, the Passive Optical Athermalization (POA) works without any mechanism.

All three principles will be materialized for a typical narrow-field lens (HFOV about 12o) with high aperture (aperture based F-number 1.3) for the actual uncooled reference detector (17micron VGA). Several design examples show the impact of lens materials on spatial lens resolution and on overall length. Pros and cons of different passive athermalization principles are evaluated in regards of housing design, availability of materials and costing.

9249-7, Session 2

Protection performance evaluation regarding imaging sensors hardened against laser dazzling

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Electro-optical imaging sensors are widely distributed and used for many different tasks in military operations and civil security. However, their operational capability can be easily disturbed by laser radiation. The likeliness of such an incidence increased dramatically in the past years due to the free availability of high-power laser pointers. These laser systems, offering laser powers of several watts, pose an increased risk to the human eye as well as to electro-optical sensors. Imaging sensors, such as those used in surveillance, can be easily dazzled with such lasers.

An adequate protection of electro-optical sensors against dazzling is highly desirable. Such protection can be accomplished with different technologies; however, none of the existing technologies can provide a sufficient protection. All current protection measures possess individual advantages and disadvantages.

We present the results on the performance of different protection technologies. The evaluation is based on automatic optical character recognition (OCR) of sensor images taken from scenes containing characters.

9249-8, Session 2

Evaluation of super-resolution imager with binary fractal test target

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Today, new generation of powerful non-linear image processing are used for real time super-resolution or noise reduction. Optronic imagers with such features are becoming difficult to assess, because spatial resolution and sensitivity are now related to scene content. Many algorithms make the assumption that there are local or non-local similarities among the image patterns to reduce the noise. This property, when combined to deconvolution, enhance artificially the response for standard linear test targets such as slit or edge, which can drastically overestimate in this case the measured system MTF, and even exceed the physical limits as diffraction. Indeed the regularization process usually reduces image complexity to enhance spread edges or contours. Small important scene details can be then deleted by this kind of processing. In this paper, a binary fractal test target is presented, with a structured clutter pattern and an interesting auto-similarity multi-scale property. The apparent structured clutter of this test target gives a trade-off between a white noise, unlikely in real scenes, and a very structured targets like MTF targets. Another advantage is the relative ease of manufacture of the target for laboratory or field testing. Indeed these two levels of the binary target avoid gray levels, difficult to manufacture especially in the thermal IR region.

Together with the fractal design of the target, an assessment method has been developed to evaluate automatically the non-linear effects on the acquired and processed image of the imager. The calculated figure of merit is to be directly comparable to the linear Fourier MTF. For this purpose the Haar wavelet elements distributed spatially and at different scales on the target are assimilated to sine Fourier cycles at different frequencies. The residual multi-scale noise is also calculated for range performance purpose, by analyzing statistically the Haar wavelet response disorder compared to the fractal design ground truth of the target.

For the method validation, a simulation of two different imager types has been done, a well-sampled linear system and an under-sampled one, coupled with super-resolution or noise reduction algorithms. The influence of the target contrast on the figures of merit is analyzed.

Finally, the possible introduction of this new figure of merit in existing analytical range performance models, such as TRM4 (Fraunhofer IOSB) or NVIPM (NVESD) is discussed. Benefits and limitations of the method are also compared to the TOD (TNO) evaluation method.

9249-9, Session 2

Optical design of the medium-sized solar simulator

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On account of the advantage of collimation, radiation uniformity and spectrum to simulate solar radiation (spectrum 300nm-2500nm), solar simulators are used broadly in various tests. Beijing Institute of Spacecraft Environment Engineering (BISEE) are developing and using Solar Simulators to meet testing requirements. The Medium-sized Solar Simulator is been developing now. The Solar Simulator is built in a space environment simulator which diameter of the chamber is 4200mm. They will be used in thermal vacuum tests. Its requirement are that the test area is diameter 2m, Irradiance is 500W/m2?1760W/m2, Uniformity in the test plane is no more than ±4%, Uniformity in the test volume is no more than ±5%, Collimation angle is ±2°. The paper introduces constitute, scheme and optical design of the Solar Simulator. We optimize its scheme and optical parameter fully. The Solar Simulator is a off-axis system. Its optical source are 7 air-cooling xenon lamps. Its optical system consist of lamp house with 7 lamp modules, integrator with 31 channels, window, collimation mirror with 19 segments. Shape and location of optical lens and mirrors are optimized fully. Plenty of calculation and analysis were done to the optical parameter. The calculational result indicate that performance of the solar simulator can meet requirements.

9249-10, Session 3

Software thermal imager simulator

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A software application has been developed for the simulation of the video at the output of a thermal imager according to the imager characteristics. The approach offers a more suitable representation than current identification (ID) range predictors do: the final user can evaluate the adequacy of a virtual camera as if he was using the camera in real operating conditions. Particularly, the ambiguity of the interpretation of ID range is cancelled. The application also allows for cost-

efficient determination of the optimal design of an imager and of its subsystems without over- or under-specification: the performances are known early in the development, for targets, scene and environmental conditions of interest. The simulated image is also powerful for testing of processing algorithms. Finally, the display, which can be a severe system limitation, is also fully considered in the system.

The application consists in Matlabtm routines that simulates the effect of the subsystems atmosphere, optical lens, detector, and image processing algorithms. Currently, the display is hardware simulated, with a computer screen, an NTSC monitor or OLED micro displays. The input scene consists in two matrices of spectral radiance and distance to the camera. Radthermtm (heat transfer simulation) is used to generate artificial scenes. Low noise high-resolution thermal images are used for more realism. The apparent radiance after path through the atmosphere is computed with Modtrantm. As for all subsystems, the level of complexity of the simulation is variable. Each pixel of the scene can be processed independently or a uniform extinction coefficient can be assumed. The atmospheric transmission, emission and diffusion are considered. The apparent radiance is transformed by the optics into irradiance in the focal plane: spectral transmittance, distortion, diffraction, aberrations, and depth of field are considered. The operator definition can be as simple as a focal length and a numerical aperture (assuming a diffraction limited PSF) and as complex as a complete optical design elaborated with Zemaxtm (professional optical design). Zemaxtm then computes the PSF by ray tracing. Alternatively, the PSF can be computed analytically from Seidel aberration coefficients. The spectral responsivity, the PSF and the pixel pitch are considered for the sampling of the irradiance image by the detector. The temporal noise is then added and the output becomes a video. The noise can be modeled but a recorded noise is preferred for a better realism (column noise, departure to the Gaussian model ...) especially for testing image-processing algorithms. Postprocessing algorithms are applied before the video is finally displayed.

The models were validated with simple cases. The realism of the simulation thus depends on the adequacy of the input scene with the application and on the accuracy of the subsystem definitions. For high accuracy results, measured characteristics should be used. These characteristics will have been validated for the simulation by a positive comparison of the experimental images from which the characteristics were extracted with the simulated images of the corresponding experimental scenes.

The ID ranges of potential imagers were assessed for various targets, backgrounds and atmospheric conditions. The optimal specifications for an optical design were determined by varying the Seidel aberration coefficients to find the worst MTF that allows the respect of the wished ID range. Zemax designs were developed and then re-introduced in the simulation for validation and final selection.

9249-11, Session 3

A target detection model predicting field observer performance in maritime scenes

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The U.S. Army's target acquisition models, the ACQUIRE and Target Task Performance (TTP) models, have been employed for many years to assess the performance of thermal infrared sensors. In recent years, ACQUIRE and the TTP models have been adapted to assess the performance of visible sensors. These adaptations have been primarily focused on the performance of an observer viewing a display device. This paper describes an implementation of the TTP model to predict field observer performance in maritime scenes.

In this implementation of the TTP model two contrast metrics were investigated, a normalised root sum of squares metric and a normalised pixel contrast metric. For a model of field observer performance, the contrast sensitivity function of the sensor system, traditionally found in the ACQUIRE and TTP models, was replaced by a contrast sensitivity function of central vision. Due to the lack of experimental data for the task discrimination criteria (N50 or V50) two approaches were taken to define N50. The first approach was to estimate N50 using the ACQUIRE-LC (ACQUIRE Low Contrast) approximation [1]. In the second approach, a measured value of N50 for small watercraft identification was used [2]. N50 was converted to V50 using the approximation equation given by [1].

Predictions of the TTP model implementation were compared to observations of a small watercraft taken in a field trial. In this field trial 12 Australian Navy observers viewed a small watercraft in open ocean scene at an elevation of 33 m. The observers rated the confidence of detecting a small watercraft on a four point rating scale. At the same time as the field observations were taken, imagery of the small watercraft was collected. Comparisons of the observed probability of detection to predictions of the TTP model implementation showed the normalised RSS metric over-estimated the probability of detection, with a maximum correlation of 0.40 between observed and predicted probability of detection. The ACQUIRE-LC N50 approximation equation was found to have poor correlation with the observed probability of detection, suggesting that this approximation is not useful for targets of this size. The normalised pixel contrast using a measured value for N50 yielded a correlation of 0.57 between the predicted and observed probability of detection. With a measured value of N50 or V50 for the small watercraft used in this investigation, this implementation of the TTP model may yield stronger correlation with observed probability of detection.

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9249-12, Session 3

Exact expressions for thermal contrast detected with thermal and quantum detectors

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The detected thermal contrast is a recently defined figure of merit introduced to describe the overall performance of a detector detecting radiation from a thermal source. We examine the detected thermal contrast for the case where the target emissivity can be assumed to be a function of the temperature and independent of the wavelength within a narrow wavelength interval of interest. Exact expressions are developed to evaluate the thermal contrast detected by both thermal and quantum detectors for focal-plane radiation detecting instruments. Expressions for the thermal contrast of a blackbody, an intrinsic radiative quantity of a body independent of the detection process, and simplified expressions for the detected thermal contrast for target emissivities which are well approximated by the grey body approximation are also given. It is found the contribution in the detected thermal contrast consists of two terms. The first results from changes occurring in the emissivity of a target with temperature while the second results from purely radiative processes. The size of the detected thermal contrast is found to be similar for the two detector types within typical infrared wavelength intervals of interest, contradicting a result previously reported in the literature. The exact results are presented in terms of a polylogarithmic formulation of the problem and extend a number of approximation schemes that have been proposed and developed in the past.

9249-13, Session 3

Performance optimization for space-based sensors: simulation and modelling at Fraunhofer IOSB

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Being able to predict the effectiveness of a space-based sensor for its designated application in space (e.g. special earth surface observations or missile detection) can help to reduce the expenses, especially during the phases of mission planning and instrumentation. In order to optimize the performance of such systems we simulate and analyse the entire operational scenario, including:

- various orbit heights and viewing angles

- system design characteristics, e. g. pixel size and filter transmission

- atmospheric effects, e. g. different cloud types, climate zones and seasons

In the following, an evaluation of the appropriate waveband for the designated sensor application can be given.

The simulation environment is also able to simulate moving objects like aircraft or missiles. Therefore, the spectral signature of the object/missile as well as its track along a flight path is implemented. The resulting video sequence is then analysed by a tracking algorithm and an estimation of the effectiveness of the simulated sensor system can be given.

This paper summarizes the work carried out at Fraunhofer IOSB in the field of simulation and modelling for the performance optimization of space based sensors.

9249-14, Session 3

Contrast analysis of space-based Earth observation infrared system

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Modeling of space-based earth observation infrared system is a challenge in which background and target features, atmosphere radiative transfer and infrared sensor system should be analyzed synthetically. We focus on development of a mathematical model considering elements mentioned above as well as a method to analyze its output.

Atmosphere radiative transfer code can be used to calculate spectral transmittance and path radiance under specified atmosphere condition and observation geometry. However, considering it time costs, it cannot be applied to large-scale scene directly. To calculate transmittance of large-scale scene, inhomogeneous atmosphere is divided into homogeneous sub-layers. Optical depths of all sub-layers are calculated using atmosphere transfer code and remain unchanged once atmosphere profiles are decided. As transmittance difference under various geometric relationships is determined by the length of transfer path and its corresponding optical depths, time is saved with acceptable accuracy loss.

Modeling of background irradiance at the sensor aperture is simplified by assuming that the scattered radiance is ignorable in medium wave infrared (MWIR) and long wave infrared (LWIR). After validating algorithm and assumption by comparing calculated earth-limb radiance with measured data, the methods of contrast and background radiance elimination are introduced. If background irradiance can be eliminated perfectly, signal-to-noise ratio (SNR) is remarkably high. However, as the influence of rough earth surface and inhomogeneous atmosphere on background radiance are simulated to be random number, residual of background irradiance becomes to the major component of noise.

For the background of a quarter of earth, the simulated images are obtained within both absorption and transmittance spectral band. A target is added into the simulated backgrounds within different spectral bands to generate composite observed images. And contrast profiles of different conditions are calculated via background and noise suppression. It can be seen that under the same geometry, better contrast and SNR can be obtained by selecting spectral band. The selection of spectral band depends on the target projection location on imaging plane. Specifically, absorption band is better at most region of earth surface, while transmittance band is better at the edge of earth disk and at the earth-limb region.

9249-15, Session 4

Low-light CMOS imaging for SWAPC active imaging systems

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The paper will overview existing active imaging applications, technologies and systems. New defence optronics applications can be accessed and adjacent markets and applications will be highlighted. The core of the paper will address the means to achieve and technical description of a novel range-gated systems that uses a new generation of high performance CMOS image sensors that feature flash and accumulation modes, adapted synchronisation circuitry and high quantum efficiency up to NIR bands to enable active imaging applications with attributes to address all SWAP-C concerns.

9249-16, Session 4

Novel eye-safe line scanning 3D laser-radar

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Regarding tasks like surveillance or automatic target recognition, especially in a non-cooperative environment, laser radar sensors offer a unique potential compared to passive sensors. Today, the civil market provides quite a number of different 3D-Sensors covering ranges up to 1 km. Typically these sensors are based on single element detectors which suffer from the drawback of spatial resolution at larger distances. Tasks demanding reliable object classification at long ranges can be fulfilled only by sensors consisting of detector arrays. They ensure sufficient frame rates and high spatial resolution. Worldwide there are many efforts in developing 3D-detectors, based on two-dimensional arrays.

This paper presents first results on the performance of a recently developed 3D imaging laser radar sensor, working in the short wave infrared (SWIR) at 1.5 µm. It consists of a novel Cadmium Mercury Telluride (CMT) linear array APD detector with 384x1 elements at a pitch of 25 µm, developed by AIM Infrarot Module GmbH. The APD elements are designed to work in the linear (non-Geiger) mode. Each pixel will provide the time of flight measurement, and, due to the linear detection mode, allowing the detection of three successive echoes. The resolution in depth is 15 cm, the maximum repetition rate is 4 kHz. We discuss various sensor concepts regarding possible applications and their dependence on system parameters like field of view, frame rate, spatial resolution and range of operation.

9249-18, Session 4

Passively-athermal, compact, STANAG-compatible laser target designator

Stephen T. Lee, Andrew Borthwick, Ian McRae, William Alexander, Thales Optronics Ltd. (United Kingdom)

Lasers intended for application to man-portable and hand-held laser target designators are subject to significant constraints

on size, weight, power consumption and cost. These constraints must be met while maintaining adequate performance across a challenging environmental specification. This dichotomy has led a number of companies to introduce low-energy 'marker' devices. These lasers can be used to mark a target for another cooperative platform but lack sufficient output energy to safely perform the function of terminal guidance (as defined for NATO by STANAG 3733). In addition the environmental performance of these marker devices is often seriously compromised. This paper presents work on a laser source with size, weight, power consumption and cost comparable to that of the lasers marketed for marking applications, while providing energy output performance that is compatible with full designator specification.

One of the challenges of operating a Nd3+:YAG laser over a broad ambient temperature range is that of diode-pump-tuning. Around 808nm, laser diodes tune at approximately 0.3nm/°C. This system is specified to operate over an ambient temperature range of –46°C to +71°C, and the system electrical power consumption requirements preclude active temperature control. As a result the laser must tolerate a 32.8nm pump wavelength range. The optical absorption of Nd3+:YAG varies dramatically over this wavelength range. This paper presents a laser that minimises the effect of this change on laser output.

A folded U-shaped geometry laser resonator is presented, made up of a corner cube at one end and a plane mirror substrate at the other. The action of the corner cube coupled with this configuration of end mirrors results in a resonator that is significantly less sensitive to misalignment of the end mirror and/or the corner cube.

This U-shaped resonator is then further folded to fit the laser into a smaller volume. Insensitivity of this compact folded resonator to mirror misalignments was analysed in Zemax via a Monte-Carlo analysis and the results of this analysis are presented.

The resulting laser output energy, pulse duration and beam quality of this athermally pumped, misalignment insensitive folded laser resonator are presented. Results for performance over an ambient temperature range of –46°C to +71°C are shown.

9249-19, Session 5

A new incremental principal component analysis with a forgetting factor for background estimation

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Human detection is an elementary task for security application and background subtraction is one of commonly used techniques for human detection in images. For background estimation, principal component analysis (PCA) is an available method. PCA is applied to many background images and produces a low dimensional eigenspace representing background. When an image with walking human is input, the background is estimated by projecting the input image onto the eigenspace. Since the background sometimes changes according to illumination change or due to a newly appeared stationary article, the eigenspace should be updated momentarily. A naïve algorithm for eigenspace updating is as follows. First the covariance matrix C(k) is updated as

C(k+1) = (1-?)C(k+1) ? ?I(k+1)I^t(k+1), (1)

where k represents discrete time, I(k) is a vector representing an input image at time k, and (1-?) is a forgetting factor. I^t(k) means transposition of I(k). We assume that average of I(k) is zero for simplicity without loss of generality. Then, the eigenspace is updated by solving the eigenvalue problem of the symmetric matrix C(k). This procedure is very time consuming because C(k) is a very large size matrix.

The purpose of this paper is to propose a new method to update the eigenspace approximately with exceedingly low computational cost. First, we notice that only a few dimensional eigenspace is sufficient to represent the background. In this case the covariance matrix C(k) can be approximated using a few eigenvectors u(1;k), u(2;k), ... u(M;k) as

C`(k) = ?(1;k)u(1;k)u^t(1;k) + ... + ?(M;k)u(M;k)u^t(M;k), (2)

where M is the dimension of the eigenspace which is as low as three or five. ?(1;k), ... , ?(M;k) are eigenvalues at time k arranged in descending order. From (1) and (2), C(k) can be approximated as

C`(k+1)=(1-?){?(1;k)u(1;k)u^t(1;k) + ... + ?(M;k)u(M;k)u^t(M;k)} + ?I(k+1)I^t(k+1).

The eigenvalue ?(i;k+1) and eigenvector u(i;k+1) are obtained by solving eigenvalue problem of the symmetric matrix C'(k+1). The background image I'(k+1) is obtained by projecting I(k+1) onto the eigenspace spanned by u(1;k), u(2;k), ... u(M;k) as

I'(k+1) = a(1)u(1;k) + ... + a(M)u(M;k),

where a(i) is obtained as an inner product a(i) = (u(i;k), I(k+1)). Now we define (M+1)-th eigenvector u(M+1;k) as the unit vector parallel with the residual vector I(k+1) – I'(k+1). Then if we set a(M+1:k) = (u(M+1:k), I(k+1)) we obtain

I(k+1) = a(1)u(1;k) + ... + a(M)u(M;k) + a(M+1)u(M+1;k).

Then each matrix elements C'(i,j;k+1) = (u(i;k), Cu(j;k)) can be proven to be

C'(i,j;k+1) = (1-?)?(i;k)?(i,j) + ?a(i)a(j).

We set eigenvalues and eigenvectors of this symmetric matrix to be ?(i) and v(i). Then ?(i;k+1) and u(i;k+1) are obtained as

?(i;k+1) =?(i), u(i;k+1) = v(i,1) u(1;k) + ... + v(i,M+1) u(M+1;k).

Thus, eigenvalues ?(i;k+1) and eigenvectors u(i;k+1) at time k+1 are obtained from eigenvalues ?(i;k) and eigenvectors u(i;k) estimated at time k and the input image I(k+1) at time k+1. In this way eiganvalues and eigenvectors are updated sequentially. Since the size of symmetric matrix C' is very small eigenspace updating can be proceeded with exceedingly low computational cost, which has been confirmed by computer simulation.

9249-20, Session 5

An embedded face-classification system for infrared images on an FPGA

Javier E. Soto, Miguel E. Figueroa, Univ. de Concepción (Chile)

We present a face-classification architecture for long-wave infrared (IR) images implemented on a Field-Programmable Gate Array (FPGA). The circuit is fast, compact and low power, and can recognize faces in real time and be embedded in a larger image-processing and computer vision system operating locally on an IR camera.

The face classification algorithm uses Local Binary Patterns (LBP) to perform feature extraction on each IR image. First, each pixel in the image is represented as an LBP pattern that encodes the similarity between the pixel and its neighbors. Uniform LBP codes are then used to reduce the number of patters to 59 while preserving more than 90% of the information contained in the original LBP representation. Then, the image is divided into 64 non-overlapping regions, and each region is represented as a 59-bin histogram of patterns. Finally, the algorithm concatenates all 64 regions to create 3,776-bin spatially enhanced histogram, which can be compared to a database of known faces using the Euclidean distance.

In order to make the hardware implementation of the algorithm more efficient, we reduce the dimensionality of the enhanced histogram using Linear Discriminant Analysis (LDA), which applies a linear transformation to the histogram vectors using a matrix computed from a training set of known faces. This allows us to reduce dimension the stored patterns vector from 3,776 to 52 for a database of 53 subjects. This reduces the local storage requirements from 1,563KB to only 43KB and enables us to store the entire database on-chip. During classification, the circuit applies the previously described LBP and LDA

algorithms to each incoming IR image in real time, and compares the resulting feature vector to each pattern stored in the local database. We use the Manhattan distance to perform the comparison because it reduces the arithmetic complexity of the distance metric.

We designed a pipelined architecture that implements the algorithm described above and exploits the parallelism available in the hardware, and mapped it onto a Xilinx XC7A100T FPGA. The circuit receives 81x150-pixel images from an independent face-detection circuit operating on the output of a CEDIP Jade UC33 IR camera. We tested the circuit with the UCHThermalFace database, which contains 28 images of 53 subjects in indoor and outdoor conditions (a total of 1,484 images). We used 16 images of each subject for training and 12 for testing. A double-precision software implementation of the original algorithm without dimensionality reduction achieves a 93.9% hit ratio in both indoor and outdoors conditions. Despite using 16-bit fixed-point arithmetic, Manhattan distances and reduced-dimensionality feature vectors, our circuit outperforms the software implementation with a 98.5% hit ratio, mainly due to the improved cluster locality achieved by LDA. The circuit uses 2% of the registers, 8% of the logic tables, 41% of the block RAMs and 10% of the hardware multipliers available on the FPGA. Using a 100 MHz clock, the circuit classifies 8,230 images per second, and consumes only 428mW.

9249-21, Session 5

A texture-based architecture for face detection in IR images on an FPGA

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This paper presents a digital architecture for face detection on infrared (IR) images. We use an algorithm based on Local Binary Patterns to build a feature vector for each pixel, which represents the texture of the image in a vicinity of this pixel. We train a Support Vector Machine (SVM) to recognize textures present in a human face and then group the classified pixels into rectangular areas. These areas can then be used to track, count, or identify faces in a scene, for example.

The architecture builds a feature vector for each pixel as follows: First, the algorithm builds a 4-bit LBP for each pixel by comparing its value to its 4 immediate neighbors (up, down, left, and right). Thus, each pixel in the image is represented by one of 16 different patterns. Next, we build a Uniform LBP (ULBP) by also considering the diagonal-neighbor pixels, but only assigning a unique code to the patterns that have two or more transitions. This ULBP assigns one of 59 possible patterns to each pixel. Next, for each 16x16-pixel overlapping region in the image, we build a 59-bin histogram of the ULBPs present in the region; and for each of the 4 8x8-pixel quadrants of the region, we build a 16-bin histogram of the 4-bit LBPs. The texture that represents the region is built as the concatenation of the histograms of the ULBP 4 LBPs, resulting in a 123-element feature vector.

An SVM decides whether each feature vector represents a face texture. We used a database of 102 subjects, each one represented by 6 IR images. We trained the SVM with random feature vectors from 51 subjects, as well as 50 additional IR images without faces in them. In order to relax the requirements on the hardware, instead of first computing the histograms and then the 123-element dot product, our architecture computes the dot product on-line as the new bin values of the histogram are being computed. As a result, the SVM does not require the use of hardware multipliers and can operate with a small memory buffer that stores the partial products associated to the last 15 lines of the input image. Finally, an algorithm for connected components analysis scans the image and encloses the detected faces in rectangular boxes.

We implemented our pipelined architecture on a Xilinx XC6SLX45 FPGA and tested it on IR images of the remaining 51 subjects of our dataset. The circuit correctly detects 100% of the faces in the images, and reports 4.5% of false positives, which correspond mostly to exposed skin in arms and hands. We also used a different set of images with more varied poses and backgrounds, and obtained a hit rate of 94.5%, with 7.2% false positives. The circuit uses 10% of the registers, 25% of the logic tables, and 24% of the block RAMs available on the FPGA. It can process 313 640x480-pixel images per second with a 100MHz clock, and consumes 266mW of power.

9249-22, Session 6

Research topics on EO systems for maritime platforms *(Keynote Presentation)*

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Our world is constantly changing, which has its effect on worldwide military operations. There is a change from conventional warfare to a domain with asymmetric threats as well. The availability of high-quality imaging information from electro-optical sensors is of high importance, for instance for timely detection and identification of small threatening vessels within a large amount of neutral vessels. Furthermore, Rules of Engagement often require a visual identification before action is allowed.

The challenge in these operations is to detect, classify and identify a target at a reasonable range, without many false alarms or missed detections. Nowadays limitations in sensor performance occur, due to the effects of sunglinths and spray which are not well modeled in the detection filters yet. For identification the signal-to-noise ratio and the resolution on the target is still limiting. Besides, the influence of the environment can reduce the sensor range in such a way that the operational task becomes challenging or even impossible. For this reason, Tactical Decision Aids will become an important factor in future operations.

In this paper, we describe current research within the Netherlands on this topic. Operational improvements such as a better all-weather capability and increasing operational sensor ranges are expected by: 1) A better integration of different EO systems in an integrated sensor suite on new and current platforms, 2) Improvement of the operational prediction of sensor performance so that the different EO sensors can be better employed depending on the current weather and environmental conditions and 3) improvement of the signal processing of the EO sensors, especially for better detection and tracking and (support for) visual classification and identification.

The goal of “performance improvement of future and current systems” is to improve the performance of recognition and other tasks for EO systems on board of ships, in relation to the other sensors on board of the ship. Different sensors and sensor concepts are studied. We focus on new, low-cost and COTS imaging EO systems which can be applied on future and current ships, and at various changing locations and circumstances, e.g. with sunshine and rain at the North Sea but also in the Caribbean and Somalia.

The goal of “Environment modelling” is to improve the predicted EO sensor performance by using on-board real-time environmental data and ship signatures in the prediction models. Focus is on the performance of the sensor in the detection and classification of non-stationary, asymmetric targets. These have relatively much, and dynamic interaction with the sea surface. Typical algoritms are prediction of a detection range against specific targets, modeling a synthetic camera image, usage of real-time meteo and propagation modelling.

The goal for “Signal processing methods” is to improve the detection and visual recognition and identification of targets and threats by improving the information extraction for the different camera systems. These automatic detection, tracking, classification and identification algorithms should be applicable to a large range of targets (e.g. both large targets and small targets) and should increase the operational added value of the EO sensors within a (multi-)sensor suite.

9249-23, Session 6

Ship recognition for improved persistent tracking with descriptor localization and compact representations

Sebastiaan P. van den Broek, Henri Bouma, Richard J. M. den Hollander, Henny E. T. Veerman, Koen W. Benoist, Piet B. W. Schwering, TNO Defence, Security and Safety (Netherlands)

In naval operations, such as piracy prevention, surveillance takes place for a longer time, in large areas, with irregular intervals of observation of ships. Knowing if an observed ship has been seen before is helpful for different reasons. If from a distance it can be known whether a ship was earlier assessed as non-threatening, it does not require further observation time. Furthermore, if the history of a ship is known, this can help to predict its intent, for example based on whether the ship has been seen in a suspect location, or if its behavior in time makes it suspicious. When intent of ships can be predicted, it may help planning the use of assets such as UAVs to more efficiently cover a (larger) surveillance area. This paper describes the research on determining the effective use of features obtained from electro-optical systems, in aiding the long-term tracking of small ships. In earlier work, the scale-invariant feature transform (SIFT) descriptors in infrared recordings was found to be useful, even with low detail imagery of ships. In this paper, we propose a novel way to use the combination of a compact fixed-size representation of the descriptors and descriptor localization. An evaluation is performed to assess the usefulness in persistent tracking, especially for larger intervals (i.e. re-identification of ships). From the evaluation on recent recordings of imagery, it is estimated how well the system discriminates between different ships.

9249-24, Session 6

Turbulence mitigation methods and their evaluation

Adam W. M. van Eekeren, Judith Dijk, Klamer Schutte, Piet B. W. Schwering, TNO Defence, Security and Safety (Netherlands)

In general, long range detection, recognition and identification in visual and infrared imagery are hampered by turbulence caused by atmospheric conditions. The amount of turbulence is often indicated by the refractive-index structure parameter Cn2. The value of this parameter and its variation is determined by the turbulence effects over the optical path. Especially along horizontal optical paths near the surface (land-to-land scenario) large values and fluctuations of Cn2 occur, resulting in an extremely blurred and shaky image sequence. Another important parameter is the isoplanatic angle, ?0, which is the angle where the turbulence is approximately constant. Over long horizontal paths the values of ?0 are typically very small; much smaller than the field-of-view of the camera.

Typical image artefacts that are caused by turbulence are blur, tilt and scintillation. These artefacts occur often locally in an image. Therefore turbulence corrections are required in each image patch of the size of the isoplanatic angle. Much research has been devoted to the field of turbulence mitigation. One of the main advantages of turbulence mitigation is that it enables visual recognition over larger distances. In many (military) scenarios this is of crucial importance. In this paper we give a brief overview of several software and hardware approaches to mitigate the visual artifacts caused by turbulence. These approaches are very diverse and range from the use of dedicated hardware, such as adaptive optics, to the use of software methods, such as deconvolution and lucky imaging. In more detail we describe the turbulence mitigation method TNO has developed in the last years, which consists of local motion compensation, frame selection and deblurring.

In this paper we will focus on the evaluation of the performance of the TNO turbulence mitigation method. An evaluation is done on some representative sequences containing turbulence captured during a NATO SET 165 trial in Dayton. The benefits and computational costs of different processing steps will be evaluated using quantitative measures. The amount of blurring and tilt in the imagery are relevant measures for such an evaluation. It is shown that the presented TNO turbulence mitigation method improves the imagery by reducing the blurring and tilt and therefore enlarges the recognition range.

9249-25, Session 6

NVG-the-Day: towards realistic night-vision training

Maarten A. Hogervorst, Frank L. Kooi, Piet Bijl, TNO Defence, Security and Safety (Netherlands)

Current night-time training using (flight-, driving-) simulators is hindered by the lack of realism. Effective night-time training requires the simulation of the illusions and limitations experienced while wearing Night Vision Goggles during the night. Various methods exist that capture certain sensor effects such as noise and the characteristic halos around lights. However, other effects are often discarded, such as the fact that image intensifiers are especially sensitive to near-infrared (NIR) light, which makes vegetation appear bright in the image (the chlorophyll effect) and strongly affects the contrast of objects against their background. Combined with the contrast and resolution reduction in NVG imagery, a scene at night may appear totally different than during the day. In practice these effects give rise to misinterpretations and illusions. When training persons on how to deal with such illusions it is essential to simulate them as accurately as possible . We present a method based on our Colour-Fusion technique (see Toet & Hogervorst, Opt. Eng. 2012) to create a realistic NVG simulation from daytime imagery, which allows for training of the typical effects experienced while wearing NVG during the night.

9249-26, Session 6

Efficient contrast enhancement through log-power histogram modification

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This paper proposes a simple and efficient method for the contrast enhancement (CE) of digital images through histogram modification. CE is an important technique in digital image processing, computer vision, and pattern recognition. Many different CE methods have been presented, several of which are based on a redistribution of the image intensities over the available dynamic range. One of the most popular CE techniques is histogram equalization (HE), which tries to fully exploit the dynamic range by creating a uniformly distribute output histogram. However, most histogram modification techniques yield over-enhancement and saturation artifacts, especially for images with sharply peaked histograms, resulting in images with an unnatural (washed out) or noisy appearance. To overcome these problems several adaptive and local methods have been developed, most of which are computationally complex and not suitable for iterative application. Here we propose a simple two-step log-power histogram modification scheme based on two standard mathematical operations: power and logarithm. The logarithm operation performed in the first step effectively removes spikes from a histogram while retaining the relationships among its components, while the power operation performed in the second step serves to approximate the shape of the original distribution. Each step involves only one parameter: the first parameter drives the redistribution of graylevel values over the available dynamic range while the second parameter determines the degree of contrast enhancement. To simplify the method further, we also present a method to automatically select the parameter used in the second (power) step. The

proposed log-power method can be applied both in a direct or an iterative mode. In the direct mode, the modified histogram is used directly to equalize the input image. In the iterative mode, the input image is processed iteratively, resulting in fast convergence after only a few iterations. Experimental results demonstrate that the proposed method produces contrast enhanced images of comparable or higher quality than those produced by current state-of-the-art methods.

9249-27, Session 6

Towards a validated synthetic human observer model for range modelling and objective sensor performance testing

Piet Bijl, Maarten A. Hogervorst, Frank L. Kooi, TNO Defence, Security and Safety (Netherlands)

End-to-end Electro-Optical system performance tests such as TOD, MRTD and MTDP require the effort of several trained human observers, each performing a series of visual judgments on the displayed output of the system. This significantly contributes to the costs of sensor testing. Currently, several synthetic human observer models exist that can replace real human observers in the TOD sensor performance test and can be used in a TOD based Target Acquisition (TA) model. The reliability that may be expected with such a model is of key importance. In an earlier study, we reported the collection and first analysis of two general sets of human observer TOD threshold data enabling the systematic test of HVS (Human Vision System) models for automated TOD sensor performance testing. The first set contains TOD data for the unaided human eye. The second set was collected on imagery processed with sensor effects, systematically varying primary sensor parameters such as diffraction blur, pixel pitch, and spatial noise. In the present study, the set was extended to display luminance and thoroughly analyzed. In addition, the set was used to validate an initial simple human observer model. Results in terms of model prediction reliability as a function of region in sensor parameter space will be reported. In the future, more models will be tested. The set will be extended to other sensor effects including dynamic noise, boost, E-zoom, or fused sensor imagery and may serve as a benchmark for competing human vision and sensor performance models.

9249-28, Session 6

Detection and tracking of humans from an airborne platform

Adam W. M. van Eekeren, Judith Dijk, Gertjan J. Burghouts, TNO Defence, Security and Safety (Netherlands)

Airborne platforms are recording large amounts of video data. Extracting the events which are needed to see is a time-demanding task for analysts. The reason for this is that the sensors record hours of video data in which only a fraction of the footage contains events of interest. For the analyst, it is hard to retrieve such events from the large amounts of video data by hand. A way to extract information more automatically from the data is to detect all humans within the scene. This can be done in a real-time scenario (both on-board as on the ground station) for strategic purposes and in an offline scenario where the information is analyzed after recording to acquire intelligence (e.g. a daily life pattern).

In this paper, we evaluate three different methods for detection of humans from a moving airborne platform. The first one is a static specific object detection algorithm. The main advantage of this method is that it can be used on single frames, and therefor does not depend on the stabilization of the platform. The main disadvantage of this method is that the number of pixels needed for the detection is pretty large. The second method is based on detection of motion-in-motion. Here the background is stabilized, and clusters of pixels that move with respect to this stabilized background are detected as moving object. The main advantage is that all moving objects are detected, the main disadvantage is that it heavily depends on the quality of the stabilization. The third method combines both previous detection methods.

The detections are tracked using a histogram-based tracker, so that missed detections can be filled in and a trajectory of all objects can be determined. We demonstrate the tracking performance using the three different detections methods on the publicly available UCF-ARG dataset. The performance is evaluated for two human actions (running and digging) and varying object sizes. It is shown that a combined detection approach (static person detection and motion-in-motion detection) gives the better tracking results for both human actions than using one of the detectors alone. Furthermore it can be concluded that the minimal height of humans must be 20 pixels to guarantee a good tracking performance.

9249-29, Session 6

Actionable intelligence from an airborne platform: automated recognition of human activities

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Airborne platforms are recording large amounts of video data. Typically, this data is collected to gather actionable intelligence. Extracting valuable intelligence is a time-demanding task for analysts. The reason for this, is that the platform usually observes a wide area for a long time. In many cases, the relevant parts of the video data concern particular human activities and events of interest. For the analyst, it is hard to retrieve such events from the large amounts of video data. In populated areas it is hard to find the few relevant events in the midst of all activities, while in desolated areas it is hard to keep focus. In this paper, we propose a method that is able to find particular human activities in video data. Our contribution is a method that extracts relevant metadata from video data in a full-automated manner, combining state-of-the-art features and techniques for human activity recognition. It can be exploited in an online, causal system for intelligence gathering.

The method comprises a chain of algorithms. First, the people are detected and tracked, by combining a generic moving object detector with a dedicated person detector. Second, state-of-the-art motion features – improved trajectories – are extracted from the tracks. Third, a model of human activities is learned from labeled examples of the activities of interest. The model is applied in a causal system: the activities are predicted for each current part of each person's track in the imagery. This enables the usage of this method in a real-time, causal system, such that intelligence can be gathered while the platform is flying and recording. The alternative usage is to analyze the data offline, after recording. The technical innovation is that our method combines the algorithms in a robust manner, resulting in a good human activity recognition capability.

We demonstrate the discriminative power of our method on the publicly available UCF-ARG dataset. Five activities have been annotated. Experiments show that the activities can be distinguished very well by our method. We have a demo available on YouTube, which shows 16 video streams, where 15 persons are walking and 1 person is running. We show that it is hard for the human eye to recognize the running person. Our method is able to instantly pinpoint the running person, by zooming in on this activity in order to highlight it for the human analyst.

9249-30, Session 7

Time-resolved thermal infrared multispectral imaging of gases and minerals

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Jahjah, Telops (Canada); Frédérick Marcotte, Pierre Tremblay, Philippe Lagueux, Vincent Farley, Telops (Canada); Éric Guyot, Telops France (France)

For years, scientists have used thermal broadband cameras to perform target characterization in the longwave (LWIR) and midwave (MWIR) infrared spectral bands. The analysis of broadband imaging sequences typically provides energy, morphological and/or spatiotemporal information. However, there is very little information about the chemical nature of the investigated targets when using such systems due to the lack of spectral content in the images. In order to improve the outcomes of these studies, Telops (Québec, Canada) has developed dynamic multispectral imaging systems which allow synchronized acquisition on 8 channels, at a high frame rate, using a motorized filter wheel. An overview over the technology is presented in this work as well as results from measurements of solvent vapors and minerals. Time-resolved multispectral imaging carried out with the Telops system illustrates the benefits of high spectral information obtained at a high frame rate when facing situations involving dynamic events such as gas cloud dispersion. Comparison of the results obtained using the information from the different acquisition channels with the corresponding broadband infrared images illustrates the selectivity brought by multispectral imaging for characterization of gas and solid targets.

9249-31, Session 7

SYSIPHE system: a state of the art airborne hyperspectral imaging system. initial results from the first airborne campaign

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The SYSIPHE system is a state of the art airborne hyperspectral imaging system developed in French-Norwegian cooperation. With a unique wide spectral range and a fine spatial resolution and high sensitivity, its aim is to validate and quantify the information potential of hyperspectral imaging in military, security and environment applications.

The system, unique in Europe and perhaps in the world, is able to provide airborne hyperspectral data covering the visible to long wave infrared domain. The VNIR-SWIR part of the system, developed by Norsk Elektro Optikk AS, is named HySpex ODIN-1024 while the MWIR-LWIR part, developed by ONERA, is named Sieleters. After a description of the different components of the system, this paper will present the first airborne campaign held over Cazaux (France) during September, 2013, the first results and the first system characteristics.

9249-32, Session 7

A next generation VNIR-SWIR hyperspectral camera system: HySpex ODIN-1024

Trond Løke, Søren Blaaberg, Ivar Baarstad, Andrei Fridman, Pesal Koirala, Norsk Elektro Optikk AS (Norway)

Recently Norsk Elektro Optikk AS (NEO) developed the HySpex ODIN-1024, a state-of-the-art hyperspectral camera covering both the VNIR and SWIR with a high spatial resolution and light gathering capability. The HySpex ODIN-1024 was developed within the SYSIPHE project, a French-Norwegian project for the development of a unique hyperspectral imaging system covering the atmospheric transmission bands in the very broad wavelength range from 0.4μm to 11.5μm. Within the SYSIPHE project completed in 2013 NEO's role was to develop a state-of-the-art hyperspectral camera for VNIR-SWIR with high resolution, high data quality, and high throughput. The first airborne campaign with the SYSIPHE system took place in September 2013. HySpex ODIN-1024 was successfully tested. The system operated as designed without failures and acquired high-quality hyperspectral data during the campaign. HySpex ODIN-1024 is a single instrument for both VNIR and SWIR with common fore-optics. Usually, covering the VNIR-SWIR range requires two separate instruments each having a separate aperture and fore-optics. With common fore-optics HySpex ODIN-1024 has a better coregistration compared to having two individual instruments for VNIR and SWIR. The optical design of ODIN-1024 enables a high resolution of 1024 pixels for the complete VNIR-SWIR data cube, high sensitivity, and low smile and keystone. In VNIR the spectral resolution is 5 nm while in SWIR the spectral resolution is 6.1 nm. A rugged opto-mechanical design ensures mechanical stability and athermalized optics. The camera utilizes state-of-the-art FPA sensors for VNIR (sCMOS) and SWIR (MCT) with low readout noise, high speed and high spatial resolution. In the VNIR part of the system resampling is used in software to correct for spectral smile and keystone. The system has an onboard-calibration facility to monitor the spectral stability of the instrument in case of variations in environmental conditions. Using a software algorithm in the onboard-calibration facility the spectra recorded airborne can be compared to spectra acquired in the laboratory. In case of a shift between the laboratory and airborne spectra the algorithm quantifies the spectral shift. HySpex ODIN-1024 also includes a real-time processing facility for real-time detection, classification, and georeferencing. Since the image-data rates are high because of the high number of pixels an internal 2x10 Gbit/s fiber optic link provides bottleneck-free data transmission crucial to uninterrupted real-time processing. We here present an overview of instrument performance as well as analysis and results from airborne data as well as lab tests.

9249-34, Session 8

CMOS-TDI detector technology for reconnaissance application

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The Institute of Optical Sensor Systems (OS) at the Robotics and Mechatronics Center of the German Aerospace Center (DLR) has more than 30 years of experience with high-resolution imaging technology. This paper shows the institute's scientific results of the leading-edge detector design CMOS in a TDI (Time Delay and Integration) architecture. This project includes the technological design of future high or multi-spectral resolution spaceborne instruments and the possibility of higher integration.

DLR OS and the Fraunhofer Institute for Microelectronic Circuits and Systems in Duisburg were driving the technology of new detectors and the FPA design for future projects, new manufacturing accuracy and on-chip processing capability in order to keep pace with the ambitious scientific and user requirements. In combination with the engineering research, the current generation of space borne sensor systems is focussing on VIS/NIR high spectral resolution to meet the requirements on earth and planetary observation systems. The combination of large swath and high-spectral resolution with intelligent synchronization control, fast-readout ADC chains and new focal-plane concepts open the door to new remote-sensing and smart deep space instruments.

The paper gives an overview over the detector development and verification program on FPA level at DLR, new control possibilities for CMOS-TDI detectors in synchronisation control mode, and key parameters like PRNU, DSNU, MTF, SNR, linearity, spectral response, quantum efficiency, CTE will be discussed in detail.

9249-35, Session 8

Optimization of InGaAs/InAlAs APDs for SWIR Detection with Demand for High Gain and Low Breakdown Voltage

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High-performance short-wave infrared (SWIR) detectors attain more and more interest, particularly for surveillance and reconnaissance applications. Using InGaAs as absorber material, these detectors can be operated with moderate or even without any cooling. Further, the significantly reduced Rayleigh scattering, in contrast to wavelengths of the visible range, enables an improved vision through fog, dust or smoke. A natural light source, i.e., “night glow” with a peak emission at around 1.6 μm can be utilized to build passive night vision devices. Even active imaging techniques can be realized using commercially available “eye-safe” lasers at 1.55 μm as illumination source. InGaAs grown lattice-matched on InP reveals a cutoff wavelength of 1.7 μm and is therefore perfectly suited for SWIR detection.

Fraunhofer IAF has started SWIR detector development based on InGaAs recently. Diodes structures were fabricated with a dry-etching mesa approach and a subsequent dielectric passivation of the mesa sidewalls. A high-resolution focal plane array (FPA) with 640 x 512 pixels and a 15 μm pixel pitch based on PIN diodes has been built up to a camera setup in cooperation with AIM Infrarot Module GmbH. Camera images with a cooled detector chip are presented along with dark current characteristics of PIN diode structures of various mesa sizes.

To handle the very low photon flux on the detector, as for SWIR surveillance applications, an internal gain is beneficial. This can be achieved by avalanche photodiodes (APDs). However, the typically high operating voltage of an APD is difficult to handle by a readout integrated circuit (ROIC), in particular for high-resolution FPAs for imaging applications. Therefore, APD structures are optimized for low breakdown voltage as well as high gain and low excess noise.

Fabricating APDs in a separated absorption-grading-charge-and-multiplication (SAGCM) layer heterostructure based on InGaAs/InAlAs comprises several advantages. Most important, the high bandgap material InAlAs as multiplication layer material allows the existence of a high electric field without suffering from strong tunneling currents. Further, InAlAs has a favorable ratio of ionization coefficients of electrons and holes compared to, e.g., InP.

In order to optimize the electro-optical performance of the device by adjusting layer thicknesses and doping profiles of the APD structure, it is indispensable to calculate the band edge profile and the electric field arising from the device design. Band edge profiles have been calculated for various doping levels and bias voltages. Based on these results, the influence of the charge layer doping level on the APD characteristics has been studied experimentally and corresponding measurement results are presented. A gain larger than 150 for room temperature operation has already been demonstrated at this early stage.

9249-36, Session 8

InGaAs focal plane array developments and perspectives

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Thanks to the various developments presently available, SWIR technology presents a growing interest and gives the opportunity to address a large spectrum of applications such as defense and security (night vision, active imaging), space (earth observation), transport (automotive safety) or industry (non destructive process control).

InGaAs material, initially developed for telecommunications detectors, appears as a good candidate to satisfy SWIR detection needs. The lattice matching with InP constitutes a double advantage to this material: attractive production capacity and uncooled operation thanks to low dark current level induced by high quality material.

In the context of this evolving domain, the InGaAs imagery activities from III-VLab were transferred to Sofradir, which provides a framework for the production activity with the manufacturing of high performances products: CACTUS320 and CACTUS640.

The developments towards VGA format with 15μm pixel pitch, lead today to the industrialization of a new product: SNAKE640. On one side, the InGaAs detection array presents high performances in terms of dark current and quantum efficiency. On the other side, the low noise ROIC has different additional functionalities. Then this 640x512 @ 15μm module appears as well suited to answer the needs of a wide range of applications.

In this paper, we will present the Sofradir InGaAs technology, the performances of our last product SNAKE640 and the perspectives of InGaAs new developments.

9249-37, Session 8

Barrier photodetectors for the short and mid-wave infrared

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Infrared detectors operating in the 2 to 3μm short-wave infrared (SWIR) and 3 to 5μm mid-wave infrared (MWIR) are finding increasing uses in applications ranging from thermal imaging to environmental monitoring and chemical threat detection. Based on relatively narrow bandgap semiconductors, these detectors suffer from undesirably high leakage currents which typically limit overall system performance. Hence such detectors are most often cooled to supress these leakage currents. It is clearly desirable to minimise the degree of cooling required for a given application, to reduce cost, weight, complexity and power consumption. Studies have shown that conventional narrow bandgap junction-photodiodes are usually limited by diffusion currents at close to room temperature, however as they are cooled Shockley Read Hall (SRH) mechanisms, and ultimately surface leakage start to dominate. This shift away from diffusion limited leakage is undesirable because SRH and surface mechanisms are characterised by smaller activation energies, meaning that leakage currents fall more slowly with reducing temperature. Recently a new class of photodetectors have been proposed and researched, referred to variously as barrier detectors, nBn detectors or xBn detectors. These are designed to remain exclusively diffusion limited as they are cooled, maximising the activation energy of the temperature dependent leakage current and hence minimising the leakage at any given temperature.

In this presentation the development and characterisation of III-V barrier photodetectors operating in the SWIR and MWIR will be summarised. In both spectral ranges, comparison with conventional junction-photodiodes shows that the barrier detector structure is effective at supressing leakage currents. At a temperature of 200 K, accessible by thermoelectric cooling, leakage current densities fall below 10-5 Acm-2 and 10-6 Acm-2 for SWIR and MWIR detectors respectively. Furthermore investigating the impact of using a lattice mismatched (GaAs) rather than lattice matched (GaSb) substrate, less than an order of magnitude increase in leakage is found, even with a thin buffer. This relatively small penalty for using a larger and cheaper GaAs substrate is of significant interest and is attributed to two important factors. Firstly, the use of an advanced interface misfit epitaxy growth technique, which accommodates the lattice mismatch between the GaAs substrate and a GaSb buffer at an abrupt interface from which few threading dislocations propagate. Secondly, the efficacy of the barrier detector structure in supressing SRH leakage associated with the increased dislocation density on the mismatched substrate.

Significantly these barrier photodetectors exhibit competitively low leakage currents at temperatures within the reach of thermoelectric cooling alone. Hence they could support a new generation of applications based on high performance at reduced cost.

9249-38, Session 8

New SOFRADIR 10μm pixel pitch infrared products

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Recent advances in miniaturization of IR imaging technology have led to a burgeoning market for mini thermal-imaging sensors.

Seen in this context our development on smaller pixel pitch has made much more compact products feasible. When this competitive advantage is mixed with smaller coolers, made possible by HOT technology, we achieved valuable reductions in the size, weight and power of the overall package.

In the same time, we are moving towards a global offer based on digital interfaces that provides our customers with simplification on the IR system design process while freeing up more space. Additionally, we are also investigating new wafer level camera solution taking advantage of the progress in micro-optics.

This paper discusses recent developments on hot and small pixel pitch technologies as well as efforts made on compact packaging solution developed by SOFRADIR in collaboration with CEA-LETI and ONERA.

9249-39, Session 8

Pyroelectric performances of relaxor-based ferroelectric single crystals and infrared detectors

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We reported in this paper our discovery of remarkably excellent pyroelectric performances in the widely investigated but still not well understood relaxor-based ferroelectric single crystalline materials of the solid solution system of Pb(B1, B2) O3 (B1: Mg2+, In3+..., B2?Nb5+, Ta5+...) and PbTiO3, which have already been considered as next-generation piezoelectric material family with super-high piezoelectric effect. As high values as 17.2?10?4 C/m2 K of pyroelctric coefficient and 40.2?10?5 Pa?1/2 of figure of merit for detectivity can be produced in the poled crystals specifically in the crystallographic direction along the spontaneous polarization, i.e. the direction of <111> in the rhombohedral phase. They show great potential as novel pyroelectric materials for wide applications in infrared detectors and thermal imagers. Commercialized infrared detector prototypes thereof have been fabricated with the specific detectivity of 1.07?109 cmHz1/2W?1, which nearly doubles that of conventional LiTaO3 single crystal based commercialized infrared detectors with similar detection mode. The relations among crystal composition, iron doping, orientation, phase structure, domain configuration and pyroelectric property, thermal parameters and dielectric proberties will also be presented here to address the physics and infrared sensor application of the strong pyroelectric effect in this complicated but promising pyroelectric materials family taking the examples of binary Pb(Mg1/3Nb2/3)O3-PbTiO3(PMNT) and ternary Pb(In1/2Nb1/2) O3-Pb(Mg1/3Nb2/3)O3-PbTiO3 (PIMNT) systems.

9249-40, Session 8

The pressure response of the frame rate in the optical readout infrared FPA imaging system

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It is quite significant to detect infrared radiation (IR) in both military and civil fields. IR detectors can be classified into quantum (cryogenic) and thermal (uncooled) detectors. The photoelectric effect is the main principle of quantum detectors. For the purpose of reducing the influence of dark current, working in a low temperature is necessary for detectors. Despite the cooled detector offering a better performance, the volume, weight and cost are limited by refrigeration equipment. The uncooled thermal detectors, such as microbolometers, pyroelectrics, and thermopiles, provide a way to solve these problems. A kind of uncooled IR imaging systems based on micro-opto-electro-mechanical systems (MOEMS) technology is known as bi-material cantilever IR FPA imaging system. The bi-material cantilever FPA system includes two different readout methods, electrical and optical readout. Each pixel in electrical readout system requires a specific peripheral circuit, resulting in a complex fabrication process and inevitable additional thermal noise. And this problem can be figured out in optical readout system. It is essential that a transducer converts the temperature change into a mechanical deflection that can be measured by an optical readout and converted into an electronic image. Since it is uncooled, low cost and more reliable than traditional IR imaging systems, the optical readout FPA system using bi-material cantilever microstructure is being widely researched in infrared imaging applications.

Because the ability of high frame rate imaging is important for IR detectors, it can be applied to observe thermal phenomenon in a short period of time, such as missile lunch, industrial processing, vehicle collision and fire detection. The optical readout FPA requires no external drive for operation and, hence, there will be no bottleneck for readout data rate. In this paper, the response limit of optical readout infrared FPA imaging system is tried to be tested and the relationship between the response time and the air pressure is carefully discussed. Firstly, a theoretical model is carried out to describe the relationship between the pressure and response time. Secondly, a substrate-free FPA for optical readout is fabricated with the pixel size of 100*100?m. Thirdly an optical readout infrared FPA imaging system is designed and built to verify the modeling analysis. Finally, on the basis of the experimental results, the methods to improve the response speed of this system by controlling the pressure are discussed.

Analyses of the frequency response of the optical readout FPA are presented in this paper. The experimental results indicate that the system response time decreases with the increase of pressure. Based on the numerical calculations, it can be predicted that the thermal time constant at atmospheric pressure will be 1/3 time of that in high vacuum. It is also

indicated that the thermal time constant will reduce to 10ms (100Hz) at atmospheric pressure. This characteristic could give a possibility to improve the response time of this novel infrared imaging system and should be of great value for practical applications.

9249-42, Session PS

Explosion-proof fiber optic fire detector: design and mathematical description

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The problem of early fire detection in areas classified as dangerously explosive is considered in this paper. Safety requirements impose stringent requirements into technical design detectors to protect such objects from the fire. Detector itself should not cause a fire. Opened conductive elements in the design of such detectors sensitive elements are the main danger. They can lead to the generation of sparks and a fire. Use of fiber-optic technology allows creating smoke and heat fire detectors, which only the sensors will be located in the protected area, and all the electronic components of signals processing may be removed at considerable distance measured by kilometers. New type of design smoke point fire detector based on fiber optic technology is considered.

Modern rates of economic development showed that the concentration of wealth per unit of the surrounding area is increasing every day. This tendency has demanded from man creating various ways to protect such property from damage, theft, destruction, etc. Fires are especially dangerous. Unfortunately, a fire at the sites of particular importance may cause technogenic or environmental disaster. Currently many companies are developing a lot of ways to control and protection of such objects from fire.

One of the most urgent tasks of Fire Defense is to protect the objects with high levels of radiation and the presence of aggressive chemicals. Ships Navy with nuclear power systems and carrying thermonuclear weapons are particularly dangerous ecologically in case of fire. On this objects traditional method of early detection of fires cannot be used or require the development of special and expensive protection.

In recent years, active work is aimed to create fire detectors based on fiber optic technology. For example, variants of thermal detectors are known wherein the optical fiber is used as a sensing element.

By analogy with linear fire detector offered different construction of fiber optic detector. The structure of the proposed detector includes:

1. Optical Power Generator;
2. The optical splitter 1x2;
3. Peaces of the optical fiber;
4. Focusing lens;
5. The signal processing unit.

A significant advantage of this detector is the rigidity of the structure compared with linear, because the lens and the fiber ends are fixed in the housing, which eliminates the possibility of displacement relative elements and defocusing of radiation.

9249-43, Session PS

Optical encryption with spatially-incoherent illumination using two LC SLMs for information input and encryption key dynamic generation

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At present time methods of optical encryption are actively developed. The majority of existing methods of optical encryption use not only light intensity distribution, easily registered with photosensors, but also its phase distribution which require application of complex holographic schemes in conjunction with spatially coherent monochromatic illumination. This leads to complex optical schemes and low decryption quality. To eliminate these disadvantages it is possible to implement optical encryption using spatially incoherent monochromatic illumination which requires registration of light intensity distribution only.

Encryption is accomplished by means of optical convolution of image of scene to be encrypted and encryption diffractive optical element (DOE) point spread function (PSF) which serves as encryption key. Encryption process is described as follows. Scene is illuminated with spatially-incoherent monochromatic light which is obtained by propagation of collimated He-Ne laser radiation through rotating ground glass. In the absence of encryption DOE lens forms image of scene in photosensor plane. DOE serves as encryption element, its PSF – encryption key. Light passing through DOE forms convolution of object image and DOE PSF. Registered by photosensor convolution is encrypted image. Decryption was conducted numerically on personal computer by means of inverse filtration with regularization. Kinoforms were used as encryption DOE because they have single diffraction order. Two liquid crystal (LC) spatial light modulators (SLM) were used to implement dynamic digital information input and dynamic encryption key change. As input scene amplitude LC SLM HoloEye LC2002 with 800?600 pixels 32?32 ?m2 and 256 gray levels was used. To image synthesized encryption kinoforms phase LC SLM HoloEye PLUTO VIS with 1920?1080 pixels 8?8 ?m2 and 256 phase levels was used. Set of test images was successfully optically encrypted and then numerically decrypted. Encrypted images contents are hidden. Decrypted images despite quite high noise levels are positively recognizable. High noise level in decrypted images is a result of significant temporal phase fluctuations in SLM HoloEye PLUTO VIS which leads to distortions of calculated kinoform and therefore its PSF. Effects of phase fluctuations can be effectively neglected with application of synchronization of SLM and light source. Experimental results of optical encryption and numerical decryption are presented.

9249-44, Session PS

Fabrication of chalcogenide glass lens module for thermal security camera

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Thermal imaging in the 8 to 12 um wavelength range was once the sole domain of the military because of the high cost of the hardware (mainly detector). With the recent development of less costly uncooled infrared detector technology, thermal cameras have been applied to a wide variety of commercial applications such as night driving, night security, and sleep lab monitoring. However, the optics, made of expensive single-crystal materials such as Ge, Si, and ZnSe, still prohibit a breakthrough for high-volume commercial systems. In addition, the key process used thermal imaging lens fabrication is single-point diamond turning (SPDT). SPDT is an expensive operation and is not compatible with high volume applications. Therefore, it is unlikely that the cost of single-crystal lenses fabricated with SPDT can be dramatically decreased to meet the price target for applications such as night vision for cars. As a potential solution to this problem, the fabrication of IR lenses using chalcogenide glasses has been studied in recent years. Because chalcogenide glass is cheaper than the crystalline materials and moldable vitreous material, the use of a chalcogenide-glass lens would be an effective way to reduce the cost of IR optics in high-volume applications. Molding is

much cheaper than mechanical turning. However, the physical properties of chalcogenide glasses are very different from the optical glasses commonly used in glass molding. Therefore, extensive studies are required to determine the optimum parameters for molding this glass.

We report on fabrication of chalcogenide-glass lens module for thermal security camera and on the evaluation of the molded chalcogenide-glass lens. Molding conditions of the lens was determined by thermal analysis; molding temperature, heating time. The moldability of chalcogenide glass was characterized through defects of lens surface and transcription properties of the mold's surface. In addition, both IR transmittance and XRD patterns of the molded chalcogenide-glass lens were evaluated to verify the compositional and structural stability of the glass material at the corresponding molding condition.

9249-45, Session PS

A novel clutter removal method based on semi-supervised regression for infrared small target detection

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Purpose:

The weak and small target detection is important task in the infrared search and tracking which plays a supporting role in wide applications such as civil and military applications. However, clutter background always causes false alarms in infrared small target detection application. Lots of methods have been proposed to estimate the background. But background estimation methods are always affected by clutters in image which lead to the false alarms. In this paper, a new clutter removal method base on semi-supervised regression is proposed to solve this problem. We not only focus the local contrast between target and background, but also consider that the non-local self-similarity of clutters. Then graph Laplacian, which represents the measure of similarity between any pair of pixels in image, is used to regularize the semi-supervised regression. Till now, the semi-supervised regression model to estimate clutter background established to preserve clutters and decrease the false alarm in small target detection application.

Methods:

Image can be model as non-stationary 2-D random fields which the data are correlated with the neighborhood pixels. So we can predict the pixel gray value used the neighborhood pixels. Thus, lots of proposed methods utilized local smooth filters to estimate the background. These methods can work well in the flat areas, but when infrared image have complicated clutters, these methods will smooth the edges and little structures which are corresponding to clutters. So in our paper, a novel clutter removal method based on semi-supervised regression is used to solve this problem.

First, we know pixel gray value can be estimated using neighborhood pixels, and then neighborhood pixels can be seen as labeled samples. So, the background estimation method can be described using semi-supervised regression model.

Then, the non-local self-similarity of clutters is utilized to preserving the edges and structure of clutter. So the graph Laplacian regularity is combined to semi-supervised model.

At last, the clutter background is eliminated from origin infrared image and constant false alarm rate (CFAR) method is used to detect targets in the image.

Results

Till now, based on the experiments we have done in the different scenes, the method we proposed can get better clutter background estimation, the estimated background preserves the context of clutter, such as the edges of clouds.

Conclusions

Conclusions can be drawn based on the results we have already got, the least trimmed square method performs well in the background estimation, and this background estimation method are clutter-preserving, it can decrease false alarm caused by clutters.

9249-46, Session PS

A regional density distribution based wide dynamic range algorithm for infrared camera systems

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Forward Looking InfraRed (FLIR) Imaging system has been widely used for both military and civilian purposes. Military applications include target acquisition and tracking, night vision system. Civilian applications include thermal efficiency analysis, short-ranged wireless communication, weather forecasting and other various applications. The dynamic range of FLIR imaging system is larger than one of commercial display. Generally, auto gain controlling and contrast enhancement algorithm are applied to FLIR imaging system. In IR imaging system, histogram equalization and plateau equalization is generally used for contrast enhancement. However, they have no solution about the excessive enhancing when luminance histogram has been distributed in specific narrow region. In this paper, we proposed a Regional Density Distribution based Wide Dynamic Range algorithm for Infrared Camera Systems.

Representative conventional methods for enhancing the contrast of an image are Histogram equalization and plateau equalization. They are widely used for infrared imaging system. However, they often introduce the significant change in luminance which causes luminance saturation and failure in object tracking.

On side of visible band cameras, Wide Dynamic Range (the same meaning as High Dynamic Range) is widely used for alternative solution of pre-mentioned problem. Most of the CCD, CMOS sensors supports this algorithm. Wide dynamic range (WDR) is describes an attribute of an imaging system that can record greater scene details, from shadows to highlights than normal. Having "wide dynamic range" is a relative term that can describe both the capability of a sensor or other imaging system, as well as the contents of an image file containing such data. The amount of dynamic range in an image which would qualify as "wide" changes over time as new systems are developed. WDR is desirable for photography and video-based systems due to its greater latitude in manipulating images.

On side of infrared band cameras, since thermal detectors (sensors) does not support WDR algorithm itself, camera manufacturer should be implement using DSPs or ASIC. And Due to the issue of real-time processing, WDR is rarely used for infrared imaging system.

We proposed a Regional Density Distribution based Wide Dynamic Range algorithm for Infrared Camera Systems. Depending on the way of implementation, the result of WDR is quite different. Our approach is single frame type WDR algorithm for enhancing the contrast of both dark and white detail without loss of bins of histogram with real-time processing.

The significant change in luminance caused by conventional contrast enhancement methods may introduce luminance saturation and failure in object tracking. Proposed method guarantees both the effective enhancing in contrast and successive object tracking. Moreover, since proposed method does not using multiple images on WDR, computation complexity might be significantly reduced in software / hardware implementation.

The experimental results show that proposed method has better performance compared with conventional Contrast enhancement methods.

9249-47, Session PS

Fault location and mechanism analysis on the CES problem

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In the process of the thermal vacuum test of the Conical Scanning Infrared Earth Sensor (CES), we found that the Earth square wave signal appeared instability?Through careful review, we found that the batch number of the device used in the preamplifier was 0913, and it was firstly that we used the batch of the device in the CES?So, after it happened, we entrusted the company analysed reliability of device to make DPA analysis of the batch of devices?And they found that the chip layout and size of the batch of the device was not consistent with the other batch of devices?On this basis, we assembled a device of the batch into a normal CES, then we reproduced the failure phenomenon in the long cable?Through the fault tree analysis(FTA) and fault location experiments, it concluded that the operational amplifiers with different batches have different electrical parameters, and it appeared instability when the CES worked in the long cable?

Then, we performed mechanism analysis on the CES's problem, including establishing the mathematical model of cable, characteristic testing on the amplitude-frequency and phase-frequency, circuit simulation and frequence compensation. After establishing the mathematical model of cable, we gived the calculation formula of cable's inductance, resistance and capacitance?Through characteristic testing on the amplitude-frequency and phase-frequency of the preamplifier circuit, we found that circuit stability problem appeared in the long cable?Then, we used ADS software(Agilent Technologies.) to perform circuit simulation?If we should not assign the pole and zero of the operational amplifier, the simulation result meet the stable osillation condition; otherwise it would reduce the phase-frequency curve slope in the place of unit gain, and the circuit was not easy to enter the stable osillation state?If we connect the inverse input and noninverse input of preamplifier circuit with compensation capacitor, it would suppress the oscillation?Finally, we performed lots of circuit simulation for different values of compensation capacitor, the results showed that the capacitor was too small not to suppress osillation, and the capacitor was too big to shift the gain and phase remarkably, and the amplitude-frequency and phase-frequency characteristic of the preamplifier circuit should be perfect if we choose the values 2200pF of compensation capacitor?

This paper gives a kind of method of fault location on the CES's problem, and performs mechanism analysis on the circuit stability problem, then gives a kind of method of frequence compensation?A series of ground experiments and simulations are designed to verify the effectiveness of this method?At present, the method has been successfully applied to the lots of satellites in low earth orbit?

9249-48, Session PS

Infrared target detection in large field of view using visual attention

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Purpose: High-resolution, multi-pixels and large field of view (FOV) infrared (IR) detector is an important research direction, which greatly improves the target detection capability. However, as the aggrandizement of FOV, the traditional spatial filtering methods based on pixel operation are impracticable, and real-time performance encounters a severe challenge. Human visual system (HVS) could selectively concentrate attention into several regions when inspecting complex scenes, as is the visual attention mechanism. Visual attention facilitates our ability to rapidly locate the most important information in a scene, so as to reduce the computational load and processing difficulty. Therefore, it is useful to analyze infrared image of dim target with visual attention.

Methods: This paper addresses the infrared target detection under the guidance of attention mechanism. Firstly, according to the biological visual theory, we research the reasons that produce visual saliency in frequency domain and know the aperiodic component corresponding to the saliency. Further, a novel saliency detection method, named spectrum of Fourier transform (SFT), is presented to calculate feature regions of infrared image.

In order to achieve the saliency map for different size of infrared targets adaptively, this paper expands the SFT to the frequency scale-space. It establishes a spectrum family, which is the convolution result of the spectrum and the Gaussian kernels of various scale. Based on the principle that local maxima over scales of normalized derivatives are likely corresponding to interesting structures, we implement the automatic scale selection Gaussian kernel in frequency domain.

Last, the paper defines a discriminant function with the threshold of similarity and adjacency, so as to obtain the final target saliency map. The appropriate image segmentation is adopted to extract candidate targets from the target saliency map. Furthermore, sieving and fusion with the neighborhood regions according to the gray correlation principle is used to avoid dividing target into multi saliency maps.

Results: Experimental results using a wide range of real IR images demonstrate that the proposed algorithm flow is effective and befitting for the infrared target detection in large FOV. It not only can solve the problem that the detection probability of infrared target is not high while the false probability is higher under complex background, but also has good performance for real-time process and engineering realization.

Conclusions: The proposed algorithm is robust and effective, yielding satisfying results for infrared target detection in large FOV with complex background and low SNR. With the new designed saliency map detection framework, we can rapidly locate the potential target regions. The saliency detector is also able to search both small and large salient regions, as well as inhibit repeated patterns in cluttered images. Automatic scale selection of the Gaussian kernel makes the infrared target detection more flexible in practical application.

9249-49, Session PS

Improvement of quality of optical reconstruction of digital Fourier holograms displayed on phase-only SLM by its digital preprocessing

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Digital holography is popular tool for research and practical applications in various fields of science and technology. Reconstruction of images from digital holograms can be accomplished numerically and optically. Most widespread method of optical reconstruction implements digital hologram display on spatial light modulators (SLM). Optical reconstruction of digital holograms is used for remote display of static and dynamic 2D and 3D scenes, in optical and optoelectronic information processing, metrology, interferometry, microscopy, etc.

Holograms recorded with digital cameras are amplitude type. Therefore quality of its optical reconstruction with phase SLM is worse compared to amplitude SLM. However application of phase SLM can provide higher diffraction efficiency. To improve quality of optical reconstruction with phase SLM, method of SLM phase modulation depth reduction at digital hologram display is proposed. To our knowledge, this method was applied only in analog holography. Also two other methods of quality improvement are considered: hologram to kinoform conversion and holograms multiplexing.

Numerical experiments on modelling of digital Fourier holograms recording and their optical reconstruction by phase SLM were performed. Characteristics of phase-only SLM HoloEye PLUTO VIS were chosen as a basis for modeling of optical image reconstruction: quantity of pixels is not higher than 1920?1080, pixel size is 8?m?8?m, number of phase levels is 256. As quantitative criterion of reconstructed images quality, normalized standard deviation (NSTD) between reconstructed and initial images was used.

Method of SLM phase modulation depth reduction at digital holograms display was proposed and tested. Contour, non-contour binary and grayscale test images with size of 128?128 pixels were used. SLM phase modulation depth ranged from 0 to 2ϖ. Quantity of hologram phase levels equal to 256 corresponds to 2ϖ phase modulation depth. To keep SLM settings while changing phase modulation depth hologram phase distribution was renormalized instead. Dependencies of NSTD on hologram phase modulation depth were obtained. NSTD minimum value is achieved at phase modulation depth equal to 0,27ϖ÷0,31ϖ. Corresponding NSTD values lie in range 0.02÷0.06. These values are 5 times lower compared to maximum phase modulation depth (2ϖ).

Speckle noise is one of the main factors that lead to degradation of quality of reconstructed images. To reduce speckle noise, hologram multiplexing can be applied. Modeling of multiplex holograms optical reconstruction was conducted. Speckle noise reduction was achieved.

For improvement of digital hologram optical reconstruction quality and diffraction efficiency hologram to kinoform conversion can be used. Kinoform is synthesized phase diffractive optical element which forms single diffraction order containing reconstructed image. Thus kinoform has maximum theoretically possible diffraction efficiency. For hologram to kinoform conversion, first numerically reconstructed image of object was obtained. Then this image was used for kinoform synthesis. Different iterative methods of kinoforms synthesis were compared. It was found that best quality of reconstructed images provides adaptive-additive algorithm. As a result, diffraction efficiency was increased by 4 times in comparison with hologram reconstruction.

9249-50, Session PS

Numerical simulation of aero-optical effects by laminar flow field surrounding the supersonic flying missile

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In this report, we present the effects on optical performance by laminar flow field surrounding the supersonic flying missile. Numerical simulation of aero-optical effects was conducted by computational fluid dynamics (CFD) analysis and ray tracing computation technique. Density structure surrounding the supersonic flying missile was obtained among the laminar flow field physical properties through the CFD analysis. The CFD simulations were conducted under following conditions; three altitudes (25, 35, 50 km), two velocities (Mach 4, 6), and two angles of attack (0, 10 degree). The density change in the laminar flow field was used to estimate the index of refraction by the Gladstone-Dale relation in the IR wavelength range. Then 3D optical media model was constructed with the refractive index variation data for ray tracing computation. The missile including sapphire window and IR sensor was converted into a 3D opto-mechanical structure model with their specifications. Ray sets were traced from a distant heat target to IR sensor detector surface through the 3D optical media model in consideration of laminar flow field properties or not. They were analyzed with ray set data arriving at the detector surface those variations of the IR sensor optical performance such as bore sight, effective focal length, spot size, point spread function, optical transfer function. In this whole process, making 3D optical media model was a key part of the simulation. Firstly, discretization of the gradient-index (GRIN) media was to start with isodensity points sampling from the CFD analysis results. For simulation efficiency, an effective region applicable to ray tracing computation was to be determined based on the edge-ray principle. Then the coordinates of the piled-up isodensity layers were extracted within the effective region and smoothed by local regression method to reduce effects of mesh irregularities from the CFD analysis. Sampled isodensity layers were reconstructed as B-spline surfaces with these smoothing data. The surfaces were converted into 3D optical media model in consideration of refractive index between the adjacent surfaces. At this point, it is important to determine the number of sampling layers of the GRIN media. For this, two approaches were used and compared with each other. The one is 'high' and the other is 'low' spatial sampling method. The high spatial sampling (HSS) method uses as many isodensity surfaces as possible to reflect density gradient in the 3D optical media. On the other hand, the low spatial sampling (LSS) method selects boundary layers to divide the GRIN media into several groups in consideration of abrupt density gradient change and the index of refraction between layers are optimized. The LSS method improves computational efficiency as it uses substantially less number of density layers. However, if the layers in the same group have vastly different shapes, the simulation accuracy could be degraded except bore sight error because layer curvature deviations are not considered in detail. Especially, the simulation results on the bore sight error by laminar flow field with LSS method was less than a few arcsec in the case of the supersonic missile flying above 25 km. The technical details of the simulation are presented together with other aero-optical effects.

9249-51, Session PS

Analysis on the effect of hypersonic vehicle's optical window on infrared thermal imaging system

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With the advent of a new era of military technology revolution in modern times, infrared imaging guidance technology has necessarily and inevitably becomes the trend to equip high-speed precise guided aero crafts for its high resolution, good concealment, and strong anti-interference ability. As high-speed aero crafts are flying in the atmosphere, the optical imaging detection system severely suffers from the aero-optical effect caused by the intense interaction between its optical dome and the atmosphere. The severe aero-optical effect causes the target image, detected by optical imaging detecting system, shift, jitter, fuzz and energy attenuation. The severe aero-optical effect include the flow field optical transmission effects and the aero-thermal radiation effects of the optical window. The radiation effect of optical dome and shock wave influence the imaging system severely and even cause infrared detector saturation. So the image quality of the aero-crafts optical imaging detecting system is impaired and thus the guidance precision will decrease. According to the aero-thermal effects and aero-thermal radiation effects of the optical window, the thermo-optic effect, the elasto-optical effect and the thermal deformation of the optical window are analyzed using finite element analysis method. Also, the peak value and its location of the point spread function, which is caused by the thermo-optic effect and the dome thermal deformation, are calculated with the variance of time. Furthermore, the temperature gradient influence to the transmission of optical window, the variation trend of transmission as well as optical window radiation with time

are studied based on temperature distribution analysis. The simulations results show that: When the incident light is perpendicular to the optical window, image shift is mainly caused by its thermal deformation, and the value of image shift is very small. Image shift is determined only by the angle of the incident light. With a certain incident angle, image shift is not affected by the gradient refractive index change. The optical window transmission is mainly affected by temperature gradient and thus not neglectable to image quality. Therefore, the selection of window cooling methods, needs not only consider the window temperature but try to eliminate the temperature gradient. When calculating the thermal radiation, the optical window should be regarded as volume radiation source instead of surface radiator. The results provide the basis for the optical window design, material selection and the later image processing.

9249-52, Session PS

Analytical model of avalanche heterophotodiode with separate regions of absorption and multiplication

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There is great interest to avalanche photodiodes and it grows. Normal way to describe operation of avalanche photodiodes (APD) including avalanche heterophotodiodes with separate regions of absorption and multiplication (SAM AHPD) is based on numerical calculation of well-known integral relations and it is very laborious. Method is not pictorial and very difficult in applying for solving related problems. Our task is calculation of tunnel currents during avalanche multiplication of charge carriers. Presented approach is based on the following assumptions. 1. Using of analytical expression for breakdown electric field generalizing well-known Sze-Gibbons relation for infinite thickness of sample to finite thickness facilitates greatly in solving problem. 2. Using of quasi-uniform electric field (QUEF) approximation helps greatly in tunnel current calculation. This approximation is acceptable in electric fields range where avalanche multiplication takes place. QUEF approximation gives slightly smaller thickness of barrier than in reality and hence gives higher values of tunnel current. Therefore, calculated slightly higher values of tunnel currents provide technological margin that is useful keeping in mind sharp dependence of APD’s tunnel current on heterostructure’s parameters. 3. Calculation of tunnel currents at avalanche breakdown voltage makes task easer workable and provides technological margin as well. 4. Avalanche breakdown should be controlled by wide-gap multiplication region but at the same time wide-gap base would punched-through and space charge region penetrates into narrow-gap absorber. 5. Choose APD’s base conductivity type with impact ionization coefficient of minority charge carriers larger than majority. 6. It is necessary to account tunneling in wide-gap multiplication region.

Provisions 1-6 give opportunity to develop formulas for dopant concentration in multiplication region at which tunnel current will be minimal and determine its value. It is possible to determine analytically optimal specification of heterostructure like “low-high-low” which would provide simultaneously minimal values of tunnel current and avalanche noise-factor.

9250-1, Session 1

Time-resolved SPAD and SiPM imaging *(Invited Paper)*

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In this paper we discuss recent advances in the field of time-resolved imaging sensors based on single-photon avalanche diode (SPAD) technology. The same technology is the core of another important class of sensors, collectively known as silicon photomultipliers (SiPMs). SPAD image sensors and SiPMs come in different flavors, analog and digital, depending on the applications they are designed for, the main variables being pitch, resolution, and size [1]. In time-resolved imaging, size is important since it determines the requirements on skew and jitter at pixel level [2]. Thus, a systematic analysis of the architecture in this context is of paramount importance, especially in the early stages of the design. Pixels too need special attention during design since they determine the ultimate performance of the sensor in terms of sensitivity, and time resolution.

The core of photon-counting pixels is the SPAD. Solid-state SPADs have shown their versatility in many time-resolved image sensors, while compactness and low cost have only accelerated their acceptance in mainstream science and engineering communities, as a valid alternative to photomultiplier tubes (PMTs). The first SPADs implemented in planar technology have emerged relatively recently [3],[4]. But, while the physics of solid-state SPADs is well understood [5],[6], it is only with the advent of devices integrated in conventional CMOS processes [7], that the evolution onto smaller and smaller feature sizes has rapidly advanced to the point that it has now become possible to envision megapixel-size imaging systems based on SPADs and large area SiPMs [8],[9]. Since a SPAD is essentially a pn junction biased above breakdown, it requires avalanche quenching and recharge mechanisms. The avalanche generation and quenching upon photon detection, is a complex mechanism that requires ultra fast active or passive circuitries to prevent the destruction of the device, while recharge circuitries prepare the SPAD for the next detection cycle in controlled manner, so as to reduce the chance of afterpulsing and/or additional dark counts [10],[11].

At the image sensor level, there are opposite trends. On the one hand, in analog SiPMs simplicity is preferred so as to maximize fill factor, and thus photon detection efficiency (PDE). On the other hand, in digital SiPMs functionality is preferred, so as to compensate various nonidealities and, to some extent, noise. Noise in SPAD image sensors, characterized in terms of dark count rate (DCR), can be controlled using a number of circuital techniques and also by operating at low temperatures, thus the emerging field of cryogenic SPADs or cryoSPAD technology. With more and more complex digital SiPMs and SPAD image sensors, comes advanced data processing and ultra-fast readout schemes, which require mechanisms capable of reducing data rate, such as event-driven and data-aware sparse readout systems, for instance. In the paper, we will describe the most common architectures and the most useful techniques for fast and energy efficient readout

[12],[13],[14],[15],[16].

To conclude, the paper outlines the trends and technology directions in the field in terms of materials and architectures, as well as the applications and new opportunities that emerge from technological advances and novel photon counting paradigms [17],[18],[19],[20].

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9250-2, Session 1

Statistical analysis of dark count rate in geiger-mode avalanche photodiode focal plane arrays

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We present a temporal statistical analysis of the array-level dark count behavior of Geiger-mode avalanche photodiode(GmAPD) focal plane arrays in 32x32 and 32x128 formats for two different wavelengths—1.0 ?m and 1.5 ?m. Assuming that dark count occurrences are Poissonian in nature, we expect that the "inter-arrival" times between successive counts will obey an exponential distribution. Deviations from the intrinsic Poissonian behavior are classified as crosstalk counts. This analysis is extended to devices of varying active area. We also include the results of devices with an epitaxially grown "filter" layer beneath the avalanche layer of the GmAPD structure to promote broadband absorption of crosstalk photons. Lastly, we present a complementary spatial analysis of crosstalk events that agrees well with the temporal results.

9250-3, Session 1

Design and performance analysis of multilayer nested grazing incidence optics

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X-ray pulsar navigation, with strong reliability, good stability, high accuracy and wide applicability, is suitable for completely autonomous navigation of near-Earth space and deep space exploration spacecrafts. As a new autonomous navigation technology with great potential for development and an excellent choice to improve the performance of spacecraft autonomous navigation system, it has extremely important strategic significance and practical engineering value and has received extensive attentions in academic and engineering domains. The measurement accuracy of X-ray photon Time of Arrival (TOA) determines the pulsar navigation accuracy. Through the design of X-ray optics, increasing the effective detection area, reducing background and improving the signal to noise ratio of the measured pulse profile, the pulse arrival time measurement accuracy can be improved. Extensive studies have shown that soft X-ray, with energy range 0.1-10keV, is suitable for pulsar navigation. Traditional optics cannot realize the focusing and collection of the X-ray photons in this energy range, and grazing incidence optics is a widely adopted choice.

We have developed X-ray grazing incidence optics with a single mirror in our previous work, it can be used to demonstrate and test on ground to verify the feasibility of X-ray detection system. But it is unable to meet the space X-ray detection and X-ray pulsar navigation requirements due to small effective area and large mass. To solve this problem, there is an urgent need to develop multilayer nested grazing incidence optics. Multilayer nested grazing incidence optics consists of multilayer mirrors to form a coaxial and confocal system to maximize the use of space and increase the effective area.

In this paper, aiming at the future demand of X-ray pulsar navigation, design optimization and analysis of nested X-ray grazing incidence optics were implemented. According to the relevant requirements, optical design of multilayer nested grazing incidence optics was carried out, recurrence relations between the layers of mirrors were derived, reasonable initial structural parameters and stray light reduction method was given for the optics, and theoretical effective collecting area is calculated. According to the initial structure parameters, with the maximization of effective area/mass ratio as the objective, the optical and mechanical structure and stray light eliminating structure were designed. The optical-mechanical-thermal numerical model was established using optical analysis software and finite element software to carry out stray light analysis, focusing performance analysis, tolerance analysis, mechanical analysis and thermal analysis, and the optics was optimized based on the analysis results. From the perspective of grazing incidence optics engineering applications, errors and environmental factors affecting the optical performance of the system were analyzed, providing evidence and guidance for the processing and alignment of nested X-ray grazing incidence optics.

9250-4, Session 1

Image Reconstruction and Optimization Using a Terahertz Scanned Imaging System

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Millimeter and sub-terahertz waves are frequently used for security purposes, to monitor and detect a variety of threats such as metal weapons, plastic explosives etc. Due to the limitations of array sensors typical imaging architectures utilize a point scanning schemes where the detector and transmitter are in either mono-static or bi-static configurations. Here we present here a similar monitoring system that is intended to be used for detection of metal threats that is based on a transceiver configuration operating at 345GHz. The transceiver system utilizes a Schottky-diode based multiplier and heterodyne detection geometry driven by DROs (Virginia Diodes Inc.). The output derived through a directional coupler and pyramidal horn is collimated and focused onto the target using two off-axis parabolic mirrors. In between a mirror galvanometer system, which is used to deflect the beam along X and Y axes is used to scan the target area with the terahertz beam. The reflected beam from the target area returns to the receiver following the same optical path and real-time receiver output is read out by a DAQ card after conditioning the IF signal. Imaging of the target area, at high rates, is achieved by real-time processing of the data read out via DAQ card. As is known distortions in the target area cause the image to blur especially in the corners of the field. By knowing apriori the beam configuration along the target plane the obtained images are corrected for distortions using conventional image reconstruction techniques. The target used in these studies is a metal grating. We demonstrate here that the system can successfully create images of the target area, which can be monitored on a computer system at a rate of few frames per second.

9250-5, Session 1

Non-contact measurement of an object's angular position by means of laser goniometer

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The non-contact measurements of an object's angular position (an object not connected to the measuring system in a mechanical way) is one of the most interesting modes of operation of the laser goniometer. For its operation the the laser goniometer depends on the rotation of the ring laser (RL) together with an optical polygon (OP) at approximately constant rate. With this rotation the light beam of a null-indicator (NI) mounted on the base of the system is scanned in a horizontal plane by its reflection from the faces of the rotating OP. The reference direction in the system is formed by

the normal to the reference mirror (RM), which is fixed on the base. The NI generates pulses at those moments of time when the beam falls normally on the reference mirror and on the control mirror (CM), which is mounted on the rotatable object to be measured. The light beam reflection from each face of the OP causes consequently two output pulses of the NI (from RM and CM) and the interval between these pulses defines the angle between RM and CM. To measure this angle one has to count the number of the RL output pulses falling in the interval.

An important feature of this mode is an extremely large range of measurement with high accuracy. In the case of a rather large width of an OP face (about 50 mm) and a rather small distance (about 0.2-0.5 m) the measurement range can reach a value up to 30 deg. With the usual resolution of about 0.1 arcs the laser goniometer has in this mode of operation an essential advantage against photo-electric autocollimators with their vary small measuring range. Therefore it is of great interest to carry out an investigation on this mode of operation. The results of analysis and experimental research are presented in the report.

9250-6, Session 2

Long-range 3D single-photon imaging lidar system

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Selex ES is developing a next generation 3-dimensional active imaging system based on Geiger-mode detectors for air-to-ground targeting, surveillance and identification. Geiger mode detection combines single-photon detection sensitivity with high temporal, or range, precision which provide superior performance when compared to analogue detection techniques for depth profiling. Geiger-mode detection allows weaker laser sources to be used and time-of-flight data may be acquired from significantly longer ranges. This reduces the size, weight and power requirements of the lidar system. Smaller apertures may also be used which helps to reduce the signature cross-section of the platform and lasers with low pulse energy and high repetition rate are easier to develop compared to high pulse energy, low repetition rate lasers required for conventional, analogue active imaging.

Selex is developing lidar for long-range targeting that use single-photon timing at a wavelength of 1550 nm. Results are reported for a reconfigurable design that accommodated either a 25 μm pixel diameter, single element InGaAs/InP single-photon detector that operated in a scanning mode, or an array of 32 x 32, 100 μm pitch InGaAs/InP single-photon timing array whilst operating in a non-scanning mode.

The optical system was designed to provide diffraction limited performance for both types of detector, covering a full diagonal Field of Regard (FoR) of 0.073° with a spatial resolution of 11.4 cm at 4.2 km. This allows a direct comparison between the single-pixel scanned and the non-scanned system. A tolerance analysis was performed on the optical design, the outcome of which was used to estimate the mechanical and alignment tolerances necessary to achieve diffraction limited performance. The system architecture was configured so that it could be used in either a bi-static mode, where the laser beam axis was parallel to and displaced from the optical axis of the receive channel; or a mono-static mode, where both axes were co-linear and a single aperture was used to transmit and receive. In the mono-static case the laser beam was injected into the optical system through an aperture in an annular mirror and transmitted to the target via a common transmit and receive channel.

Depth images of non-cooperative targets were recorded at ranges 2.9 km and 4.2 km using the scanned single-element system in the bi-static mode. The FoR was illuminated using an erbium doped fibre laser operating at a wavelength of 1550 nm, which generated 800 ps pulses at a repetition rate of 125 kHz and with an average optical power of 0.5 W. Photon returns from the target collected by the optical system were recorded by the detector operating in a gated mode. The FoR was scanned using a pair of galvanometer mirrors providing a high accuracy x,y position adjustment at a step size equal to the spatial resolution. The data was acquired over 32 x 32 scan points from which an assessment of scan rate vs. acquisition rate was performed. This data allowed the build-up of the 3D point cloud to be analysed as a function of acquisition time for different targets at various ranges.

One of the main mono-static system issues of backscatter was analysed for the system. Both backscatter levels and intensity distribution at the detector focal plane were investigated for the scanned and non-scanned systems.

9250-7, Session 2

Lidar on small UAV for 3D mapping

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Small UAV:s (Unmanned Aerial Vehicles) are currently in an explosive technical development phase. The performance of UAV-system components such as inertial navigation sensors, propulsion, control processors and algorithms are gradually improving. Simultaneously, lidar technologies are continuously developing in terms of reliability, accuracy, as well as speed of data collection, storage and processing. The lidar development towards miniature systems with high data rates has, together with recent UAV development, a great potential for new three dimensional (3D) mapping capabilities. Compared to lidar mapping from manned full-size aircraft a small unmanned aircraft can be cost efficient over small areas and more flexible for deployment. An advantage with high resolution lidar compared to 3D mapping from passive (multi angle) photogrammetry is the ability to penetrate through vegetation and detect partially obscured targets. Another advantage is the ability to obtain 3D data over the whole survey area, without the limited performance of passive photogrammetry in low contrast areas. The purpose of our work is to demonstrate 3D lidar mapping capability from a small multirotor UAV. We present the first experimental results and the mechanical and electrical integration of the Velodyne HDL-32E lidar on a six-rotor aircraft with a total weight of 7 kg. The rotating lidar is mounted at an angle of 20 degrees from the horizontal plane giving a vertical field-of-view of 10-50 degrees below the horizon in the aircraft forward directions. For absolute positioning of the 3D data, accurate positioning and orientation of the lidar sensor is of high importance. We evaluate the lidar data position accuracy both based on an inertial measurement unit (IMU) combined with GPS-data and based on combined IMU, GPS, and photogrammetry data. The IMU sensors consist of accelerometers, gyroscopes, magnetometers, and a pressure sensor for altitude correction. For the photogrammetry-assisted positioning we use data from a camera hard-mounted to the lidar frame. The lidar range and angular resolution and accuracies are documented as well as the capability for target surface reflectivity estimation based on measurements on calibration standards. The general mapping capability including the detection of obscured targets is demonstrated through field data collection and analysis.

9250-8, Session 2

Passive and active EO sensing close to the sea surface

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The present paper investigates the use of an eye-safe laser rangefinder at 1.5 μm and TV/IR imaging to obtain information on atmospheric properties at various paths close to the sea surface. This knowledge can in turn be used to predict EO

sensor performance. The paper will describe the experimental equipment and the results from measurements of atmospheric backscatter as well as TV and IR images of test targets along a 1.8 km path close to the Baltic Sea. The site also contains a weather station and a scintillometer for logging weather and turbulence parameters. Results correlating the lidar attenuation with the imaging performance will be given and compared with models.

9250-9, Session 2

Synthetic aperture Ladar concept for infrastructure monitoring *(Invited Paper)*

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Synthetic Aperture Radar (SAR) is a mature technology that overcomes the diffraction limit of an imaging system's real aperture by taking advantage of the platform motion to coherently sample multiple sections of an aperture much larger than the physical one. In more recent years, Interferometric SAR (InSAR) and Differential Interferometric SAR (D-InSAR) have become powerful tools adding high resolution elevation and change detection measurements. State of the art SAR systems based on dual-use satellites are capable of providing ground resolutions of one meter; while their airborne counterparts obtain resolutions of 10 cm. D-InSAR products based on these systems can produce cm-scale vertical resolution image products.

Long range surveillance of infrastructure is a critical need in numerous security applications, both civilian and military. Deformation monitoring of railways, roads, buildings, cellular antennas, power structures (i.e., power lines, wind turbines, dams, nuclear plants) would benefit from improved resolution, both in the ground plane and vertical direction. The ultimate limitation to the achievable resolution of any imaging system is its wavelength. SAR systems typically operate in the wavelength range of about 30 cm to 3 cm. The natural extension to improve resolution is to thus decrease the wavelength, i.e. design a synthetic aperture system in a different wavelength regime. One such system offering the potential for vastly improved resolutions in three dimensions is Synthetic Aperture Ladar (SAL). This system operates at infrared wavelengths, from about 1.5 μm to 9 μm which is about ten thousand times smaller than for SAR.

Over the last decades, studies from different groups have been done to validate the feasibility of a SAL system for 2D imagery and more recently for 3D static target imagery. This paper presents simulations as well as laboratory demonstrations of deformation mapping using a synthetic aperture ladar system operated at 1.5 μm. The transmitter and receptor of the fiber-based system are mounted on a translation stage which move at a constant speed relatively to the target (sand) located 25 cm away. The change in the 3D profile of the target is thereafter monitored with sub-millimeter precision using the multiple-pass SAL system.

9250-10, Session 2

Range resolution improvement of phase coded lidar system utilizing detector characteristics for short codes acquirement

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The traditional phase coded lidar systems require the collection of every returned laser pulse and are restricted in range resolution by sampling frequency and subpulse width. A phase coded lidar system with high range resolution is proposed with the accumulated m-sequence acquisition method for signal detection. The detector accumulates kN-1 or kN+1 bits of the emitted laser sequence to deduce the Nth or 1st bit of the sequence. The indoor experiment achieved 2 us resolution with the sampling period of 28 us by employing a 15-bit m-sequence. This method achieves the acquisition of m-sequence with narrow subpulse width whereas the sampling frequency is kept low. The experiment results showed an approach to implement the phase coded imaging lidar into practical application.

9250-11, Session 3

3DLASEM: simulation of three-dimensional flash Lidar for ocean imaging *(Invited Paper)*

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Airborne lidar has been studied since the 1970s as a means of collecting information about ocean surface and subsurface properties, and about objects in the water column and on the ocean bottom. Recent advances in flash-lidar receivers have greatly facilitated the construction of three-dimensional images of the ocean, with compact voxels that provide fine vertical and horizontal resolution, making imaging flash LIDAR an effective method for airborne searches of the ocean surface and subsurface volume. The performance of ocean LIDAR depends strongly on the sea surface (waves, whitecaps, and flotsam), on water turbidity, and on the characteristics of the objects of interest. Cost-effective design of the LIDAR system and processing algorithms requires a modeling capability that can deal with the physics of light propagation through the air-water interface, into the ocean, and back to the LIDAR receiver. 3DLASE-M is a physics-based LIDAR simulator that yields high-fidelity images for 3-dimensional algorithm development and performance predictions.

9250-12, Session 3

3D laser gated viewing from a moving submarine platform

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Range-gated active imaging is a prominent technique for night vision, remote sensing or vision through obstacles (fog, smoke, camouflage netting...). Furthermore, range-gated imaging not only informs on the scene reflectance but also on the depth of scene for each pixel.

In this paper, we discuss and present experimental results of three different methods for 3D reconstruction of scenes from the kilometric to the centimetric scale. Tomography is based on a depth-scanning of the scene with very short range-gates. Further, it is shown that the whole depth information can be reconstructed from only two images by an analysis of the active imaging intrinsic shape of the depth intensity profile. Finally, it is shown that range can be coded in the intensity image by the application of specific multiple-exposure sequences. This last technique is named "range coding". With the two last techniques it is possible to realize a depth mapping of a scene with a minimum of laser activity, which enables a nearly stealthy use of the 3D active imaging technique. However, these three 3D imaging methods are very sensitive to motion which reduces the correlation between local information and pixel position. Underwater imaging is a particular case where it is particularly difficult to stabilize the imaging platform and classical 3D reconstruction algorithms suffer from the motion between the different images in the recorded sequence. In the last paragraph of this

paper, we applied the 3D tomographic reconstruction method in such an underwater environment. As the tomographic method is particularly sensitive to motion, we applied a new method based on a combination between image registration by homography and 3D scene reconstruction through tomography. Image registration leads to the superposition of all the images from the tomographic sequence and consists in different steps. At first, we apply a corner detection by Harris method on all the images from the sequence, then the possible correspondences between consecutive images are estimated and a RANSAC algorithm removes the false correspondences. At the end, the set of images is stabilized by an homography between the best correspondences in each consecutive images. The difficulty was two find correspondences between images where the gray levels show high variation in the same sequence. After stabilisation, we use an algorithm on each pixel of the image data cube to find where the maximum intensity is reached and to create a z-map and a reflectance image with these information. The two last images (z-map and reflectance image) give the possibility to create the 3D reconstruction of the scene. In our case, a centimetric resolution could be achieved.

9250-13, Session 3

Processing of airborne lidar bathymetry data for detailed sea floor mapping

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Airborne bathymetric lidar has proven to be a valuable sensor for rapid and accurate sounding of shallow water areas. With advanced processing of the lidar data, detailed mapping of the sea floor with various objects and vegetation is possible. This mapping capability has a wide range of applications including detection of mine-like objects, mapping marine natural resources, and fish spawning areas, as well as supporting the fulfillment of national and international environmental monitoring directives. Current shallow sea floor monitoring relies mainly on localized methods based on underwater video and diver inventories. Surface covering methods with lidar have been studied but are used only to a very small extent in operational monitoring programmes. Although data sets collected by subsea systems give a high degree of credibility they can benefit from a combination with lidar for surveying and monitoring larger areas. With lidar-based sea floor maps containing information of substrate and attached vegetation, the field investigations become more efficient. Field data collection can be directed into selected areas and even focused to identification of specific targets detected in the lidar map.

The purpose of this work is to describe the performance for detection and classification of sea floor objects and vegetation, for the lidar seeing through the water column. With both experimental and simulated data we examine the lidar signal characteristics depending on bottom depth, substrate type, and vegetation. The experimental evaluation is based on lidar data from field documented sites, where field data were taken from underwater video recordings. The bottom types in the experimental evaluation are represented by hard substrate (bedrock, boulders, and stones), sand, and fine sediments. To be able to accurately extract the information from the received lidar signal, it is necessary to account for the air-water interface and the water medium. The information content is hidden in the lidar depth data, also referred to as point data, and also in the shape of the received lidar waveform. The returned lidar signal is affected by environmental factors such as bottom depth and water turbidity, as well as lidar system factors such as laser beam footprint size and sounding density.

9250-14, Session 3

Underwater laser imaging experiments in the Baltic Sea

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The survey of the maritime and the underwater environment is of high interest for modern naval situational awareness as well as for the security of local civilian and military operations like underwater engineering, geological exploration and identification of threats. Complimentary to the use of sonar technologies, active optical sensing, i.e. laser imaging, is a very promising tool for high resolution imaging and identification issues. One classical laser application to explore the underwater environment is airborne LIDAR. However, laser based sensors can also be used on underwater platforms like autonomous underwater vehicles (AUV) as an additional technology compared to sonar to be able to identify objects of interest. Surveys may include the inspection of cables and pipelines or naval applications like mine counter measures (MCM).

In the last years the French-German Research Institute Saint-Louis (ISL) and the German Naval Research Department (WTD 71-FWG) have performed different trials in the Baltic Sea to evaluate the performance of laser gated viewing (LGV) and underwater laser scanning (ULS). These experiments aimed on a quantitative evaluation of these laser imaging methods under application related conditions. Different scenarios were tested with respect to varying environmental conditions. Working near a harbor or on the open sea under sunny and calm or windy and rainy weather conditions, the measured turbidity, i.e. the attenuation coefficient of the water column, ranges from 0.4 m-1 to 3 m-1. The experiments and imaging results are discussed with respect to 2D and 3D image processing under the given environmental conditions.

9250-15, Session 3

Low-cost commodity depth sensor comparison and accuracy analysis

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Introduction

Low cost depth sensors, like the Kinect, have been a huge success in the field of computer vision and robotics, due to its ability to acquire depth images at high frame rates even in untextured environments and its low price. The same characteristics apply to the Kinect 2, a mass produced time-of-flight camera with high lateral resolution. In this paper we analyze the Kinect 2 for the XBox One and open-source drivers, allowing direct access to raw image material send from the device.

Sensor

The depth is measured pixel wise with a photonic mixer device (PMD), which is similar to CCD or CMOS camera sensors. A high frequency sinusoid signal is used to modulate the intensity of the illumination of three infrared laser diodes and the exposure of the pixels of the PMD, providing a correlation between emitted and absorbed light over time. Multiple exposures with a phase shifted signal at the PMD yield the round-trip distance of the light pules modulo the wavelength of the sinusoid signal. The phase shift for individual pixels can be programmed into the PMD.

Methods

The Kinect 2 connector is replaced by a standard USB 3 and 12 volt DC connector for an additional power supply. Data acquisition is done on a standard desktop PC running Linux, using libusb for low-level communication and an open-source driver for sensor initialization, control and data transfer. Intrinsic camera parameters of the PMD and its lens, consisting of focal length, principal point, distortion parameters and phase offsets for every single pixel, have been stored on the device

by the manufacturer and are transfered at initialization. Using these parameters, multiple exposures are combined, yielding a depth and an intensity image, showing only the light of the laser diodes and suppressing global illumination. A highly accurate calibration board featuring a circle pattern with known geometry is recorded at different locations and orientations, which can be localized in the intensity image, providing data for standard camera calibration. Furthermore, the board can be localized in the camera coordinate system, to acquire depth information for the set of pixels the board is projected on. In this way, we improve the calibration parameters, evaluate the depth accuracy of the sensor and compare it to the performance of the original Kinect.

Results

The depth data of the Kinect 2 shows the advantages of the PMD by not suffering from depth resolution falloff with increasing distances like its predecessor, due to the triangulation based depth sensing. While the measurements of the Kinect 1 contain artifacts at depth discontinuities, due to the structured light approach, the Kinect 2 is able to resolve fine structures like fingers in a much greater distance. On the other hand, high contrast can lead to blooming that strongly reduces the quality of surrounding measurements and the multiple exposures lead to the introduction of motion artifacts.

Conclusion and outlook

The Kinect 2 is likely going to replace its predecessor in most applications like robot navigation, parking assistants, gesture recognition and indoor scene analysis. By coupling it with a second infrared camera for stereo matching and triangulation the sensing range could be greatly extended while also increasing the accuracy of low range measurements. The device could be enabled for use in bright daylight, by replacing the laser diodes with higher power alternatives.

9250-16, Session 4

New fiber laser for lidar developments in disaster management *(Invited Paper)*

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Recent progresses in fiber technology have enabled new laser designs along with all fiber lidar architectures. Their asset is to avoid free-space optics, sparing lengthy alignment procedures and yielding compact setups that are well adapted for field operations and on board applications thanks to their intrinsic vibration-resistant architectures. We present results in remote sensing for disaster management recently achieved with fiber systems. Field trials of a 3-paths lidar vibrometer for the remote study of modal parameters of buildings has shown that application-related constraints were fulfilled and that the obtained results are consistent with simultaneous in situ seismic sensors measurements. Remote multi-gas detection can be obtained using broadband infrared spectroscopy. Results obtained on methane concentration measurement using an infrared supercontinuum fiber laser and analysis in the 3-4 μm region are reported. For gas flux retrieval, air velocity measurement is also required. Long range scanning all fiber wind lidars are now available thanks to innovative laser architectures. High peak power highly coherent pulses can be extracted from Er:Yb and Tm active fibers using methods described in the paper. The additional laser power provides increased coherent lidar capability in range and scanning of large areas but also better system resistance to adverse weather conditions. Wind sensing at ranges beyond 10 km have been achieved and on-going tests of a scanning system dedicated to airport safety is reported.

9250-17, Session 4

Automatic change detection using mobile laser scanning *(Invited Paper)*

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Change detection requires the comparison of multi-temporal data. By comparing live data with past data of the same area, changes can be automatically detected and identified. Special requirements must be met by the sensors and the methods used for data processing if the results are intended to support short-term operations, such as convoy escort duties or airborne surveillance. These applications require methods for immediate processing of the data. Further examples for such scenarios can be found in search and rescue missions, emergency services, or military applications. Volumetric changes in the scene can hint at suspicious activities like the movement of military vehicles, the application of camouflage nets, or the placement of IEDs, etc.

In contrast to broad research activities in remote sensing with optical cameras, this contribution addresses the topic using 3D data acquired by mobile platforms, i.e., mobile laser scanning (MLS) or airborne laser scanning (ALS). The analysis of such data does not require any reconstruction of the geometry of 3D objects, as this information is inherently included in the data. Change detection is further supported by the fact that the result is independent of natural lighting conditions and color contrasts. We present a framework for immediate comparison of current MLS data to given 3D reference data. Our method extends the concept of occupancy grids known from robot mapping, which incorporates the sensor positions in the processing of the 3D point clouds. This allows to extract the information that is included in the data acquisition geometry. For each single range measurement, it becomes apparent that an object reflects laser pulses in the measured range distance, i.e., space is occupied at that 3D position. In addition, it is obvious that space is empty along the line of sight between sensor and the reflecting object. Everywhere else the occupancy of space remains unknown. The data quality (e.g., point density, laser ranging accuracy, positioning errors) is modelled as fuzzy transitions between the states empty, occupied and unknown. This approach handles occlusions and changes implicitly, such that the latter are identifiable by conflicts of empty space and occupied space.

The proposed change detection method applies the Dempster-Shafer theory to identify conflicting evidence along the laser pulse propagation path. Additional attributes are considered to decide whether detected changes are of man-made origin or occurring due to natural effects (e.g., variations in the foliation of trees). From a methodical point of view, our approach is designed for a future implementation for on-board processing in MLS and ALS systems. Modern instruments show a trend toward increasing performance and realtime processing. We expect that an efficient implementation of the proposed methods can work in realtime on an operational system, and we expect that the model parameters that describe the data quality can automatically be set during the data acquisition. The presented concept of change detection has been successfully validated in experiments with recorded MLS and ALS data streams. Results are shown for test sites at which such data were acquired at different time intervals.

9250-18, Session 4

Investigation of frame-to-frame back projection and feature selection algorithms for non line of sight laser gated viewing

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The capacity of non-line-of-sight vision on an obscured scene has been demonstrated for laser gated viewing by the analysis of scattered photons. We recently published the experimental demonstration of the localization of single targets with a total roundtrip path length of about 10 m and the application of two distinct illumination concepts i.e. single-spot illumination and full-field illumination. In the present publication, we present the latest development in this area of laser gated viewing based computational optics. In detail, we report on two major improvements in the data analysis including the back projection and the feature selection.

While the recording of the data is realized within a few seconds, data analysis and reconstruction of the obscured scene are time consuming. Our new analysis algorithm helps to both reduce the processing time and increase the 3D resolution of the reconstruction in the obscured three-dimensional space. This algorithm is based on a frame to frame back projection of the recorded data on a pre-defined space of 3x3x3 m? with a resolution of 3 cm in each dimension. Thus, the developed algorithm increases significantly the spatial resolution and reduces the processing time. In the future this new projection algorithm could be used in a massive parallel processing (MPP) approach on graphics processing units (GPU) to further improve the processing time.

For the evaluation of new post-processing and reconstruction algorithms, a set of four different measurements (three target positions and the laboratory background) are recorded and processed by the new back projection algorithm. This data could either be used for the processing of single measurements or to generate and analyze synthetic data by composition of different signals. Thus, it is possible to quantify the performance to detect single and multiple objects form distinct positions.

New post processing algorithms were investigated and modified to comply with the needs of non-line-of-sight vision. Here, major tasks are to reduce the amount of data and to identify local maxima in a 3D voxel area. To achieve this task, various feature selection algorithms are constructed and analyzed. These filters are adapted for the application on 3D data from image processing, like Lambertian or Gaussian filters. An assessment is carried out including an evaluation of the different algorithms for 1D, 2D and (finally) 3D data.

In conclusion two major improvements on non-line-of-sight vision are presented: the frame-to-frame back projection and efficient filtering of data with automatic detection of objects.

9250-19, Session 5

Detection of people in military and security context imagery *(Invited Paper)*

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The traditional use of aerial platforms for intelligence gathering is greatly challenged by the nature of cluttered and congested urban operating environments and restricted lines of sight. and it It is likely that ground based acquisition systems will become more prevalent in the future urban operations with exploitation drawn from new and emerging electro-optic surveillance technologies. Recent and current operations in Northern Ireland, Iraq and Afghanistan undertaken by British forces and in Somalia by US troops are examples that have clearly demonstrated that for ground forces to fight effectively in built-up areas, or to act as aids to the civil power, they must first have access to current and pertinent intelligence about the existing and likely threats they face. With this information so that they can apply or can bring to bear adequate resources in an acceptable time-frame to minimise the potential for both friendly and collateral casualties.

A high level of visual surveillance implies a heavy human work-load unless the presence of threats can be automated. Automated surveillance systems must first be capable of robustly detecting individuals who may pose a potential threat within complex scenes. Our research addresses this challenge by considering the presence of persons who may be partially obscured by structures, by handling personal infantry weapons or by the tactical pose they have adopted. We applied current computer vision techniques to achieve reliable detections within two dimensional images by investigating a recently published approach based on the construction of cascaded non-linear classifiers from part-based deformable models. Performance was established by assessing how well the method detected subjects handling weapons in common operational use when tasked to undertake low level infantry tactics in the open and when obscured together with innocent civilian activities. Results were compared with published literature where the same method was applied to publically available upright pedestrian imagery.

Earlier research based on feature descriptors such as the histograms of oriented gradients (HOG) trained using the support learning vector machine approach (HOG) has shown that although this method is robust in detecting humans in images of limited quality, it fails in cases where the human subject is partially occluded or overlaps another subject. We address these shortcomings by revisiting the problem based on recently published work that focussed on the detection and association of parts???. of partially-occluded objects including persons. Bounding the location of people in a scene then opens the opportunity to apply emerging two dimensional pose classification algorithms to attempt to identify both the likely activity and the possible intent. Our findings are that the new method has the potential to become a useful people detection tool, yielding a precision of approximately 70% for a recall rate of around 85% when applied to our military context imagery.

Identifying potential local threats remains hugely challenging for the soldier on the ground that is further exacerbated in those operations where enemy combatants do not wear any identifying uniforms and may blend in with, or are part of, a local civilian population. Applying near real-time computer vision techniques to detecting individuals who may have hostile intent and pose an imminent threat could be of significant value.

9250-20, Session 5

Image quality of optical remote sensing data

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Photogrammetry and remote sensing provide procedures for deriving geometric, radiometric and thematic information from image data. A variety of aircraft and space-borne sensors are available to capture image data. Different standards and specifications of quality assessment for optical remote sensing data are available.

Due to the possibilities of absolute geometric and radiometric calibration digital sensors provide new promising opportunities to create value added products like Digital Elevation Models, land-use maps etc. Such cameras combine the high geometric quality with the radiometric standards of earth observation systems.

The determination of image quality of remote sensing data can be distinguished in (spectral) radiometric and geometric aspects. Standards contains different metrics for accuracy issues (spectral, radiometric and geometric accuracy) and for performance parameters like SNR, MTF . Image artefacts are another important topic.

The paper gives an overview of the current debate and the possibility of standardization.

9250-21, Session 5

Obtaining spectral information from infrared scenarios using hyper-spectral cameras and cameras with spinning filter wheel

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In the past decades the Norwegian Defence Research Establishment (FFI) has worked on recording and characterizing infrared scenarios for several application purposes, such as infrared target and background modeling and simulation, model validation, atmospheric propagation, and image segmentation and target detection for civilian and defence purposes. During the last year FFI has acquired several new systems for characterization of infrared radiation properties. In total, five new infrared cameras from IRCAM GmbH, Germany, are acquired. These cameras cover both the long-wavelength and extended medium-wavelength infrared spectral bands. The cameras are equipped with fast rotating filter wheels which can be used to study spectral properties and polarization effects within these wavelength bands. This option allows the sensors to operate in user-defined spectral bands, for instance the extended medium wave infrared cameras may be operated as pure medium wave or short wave cameras. Isolation of two or more narrow bands, which may contain spectral characteristics of a certain scene, can be used in image segmentation and image processing to gain more information about the scene than what can be obtained from just a pure broad band infrared image. FFI has also acquired two HyperCam sensors from Telops Inc., Canada, covering the long-wavelength and extended medium-wavelength spectral bands, respectively. The combination of imaging detectors and Fourier Transform spectroscopy allows simultaneous spectral and spatial characterization of infrared scenarios. These sensors may optionally be operated as high-speed infrared cameras. A description of the new sensors and their capabilities are presented together with some examples of results acquired by the different sensors. These examples demonstrate the principles of how the new spectral information can be used to extract for instance spectral reflection and emission properties of an object, and how certain objects can be separated from the background based on the spectral information only.

9250-22, Session 5

Performance evaluation of image-based location recognition approaches based on large-scale UAV imagery

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Introduction

Image-based location recognition is an important problem in computer vision, robotics and remote sensing. Given a query image, the aim is to infer the camera location based on the image content by finding the closest match in a database of previously indexed imagery with known location information. This paper evaluates the performance of standard approaches for location recognition using large-scale aerial imagery. We compare recognition results on different system configurations using both electro-optical (EO) and infrared (IR) data. Furthermore, we examine the induced performance loss when data from different imaging domains is used for training. Applications are widespread and include vision-based navigation, precise object geo-referencing or mapping applications.

Methods

Almost all large-scale approaches use vector quantization methods based on a learned vocabulary of visual words. For this purpose, local feature descriptors are extracted from salient regions and quantized into clusters, where each cluster represents a visual word. Each image can then be compactly described by a vector of fixed size containing the (weighted) number of occurrences of each visual word of the vocabulary. Various methods have been used for similarity calculation (e.g. L2-distance, cosine similarity) between the query image and the database of previously indexed imagery. State-of–the-art methods also model feature co-occurrence statistics in order to improve on a naïve Bayesian classification approach.

Results

Multiple experiments were carried out using a large variety of UAV-based EO and IR image data. The influence of different sizes of vocabularies, different feature detectors and descriptors and different distance metrics on recognition results is explored for EO and IR images separately. Moreover, we provide insights on the degradation of recognition accuracy when the query configuration deviates from the training setup in terms of sensor orientation, imaging modality and image quality.

Conclusion

In this paper we evaluated the quality of state-of-the-art image-based location recognition approaches by conducting extensive experiments both on EO and IR imagery in various settings. Furthermore, we analyzed the performance loss that occurs if the database consists of IR images, while the vocabulary was trained on EO data and vice versa. Our results can be seen as a guideline towards optimizing the performance of location recognition systems, especially for application in the domain of IR imagery.

Outlook

Various methods have been proposed from the image retrieval community in order to improve on existing systems, e.g. by applying Hamming Embedding, weak geometric consistency constraints or fast geometrical verification. We plan to further investigate such methods in the context of image-based location recognition. We also plan to employ visual codebook adaptation techniques in order to cope with domain changes. We will investigate by which amount it is possible to adapt existing visual codebooks to different imaging domains with just a few samples from the new domain.

9250-23, Session 5

Geometric calibration of multi-sensor image fusion system with thermal Infrared and low-light camera

Dragana Peric, Vojislav Lukic, Milana Spanovic, Radmila Sekulic, Jelena Kocic, VLATACOM d.o.o. (Serbia)

A calibration platform for geometric calibration of multi-sensor image fusion system with thermal infrared camera based on LWIR uncooled microbolometer sensor and low light camera based on CMOS sensor is presented. Thermal infrared camera has resolution 640 x 480 pixels and frame rate 50 frames per second and low light camera has resolution 1280 x 1024 pixels and frame rate 50 frames per second. Pixel fusion algorithm based on Laplacian pyramids is applied to digital uncompressed outputs from thermal infrared camera and low light camera. For an image fusion system it is important that scene in image planes of both cameras are completely overlapped to enable pixel fusion. The accurate geometric calibration of the intrinsic and extrinsic geometric parameters of cameras that uses planar calibration pattern is applied. For calibration procedure specific software is made. Patterns used in geometric calibration are prepared with aim to obtain maximum contrast in both visible and infrared spectral range - using chessboards which fields are made of different emissivity materials. Experiments were held in both indoor and outdoor scenarios.

As a result of geometric calibration, intrinsic parameters: focal length, principal point and lens distortion are obtained and used for individual cameras compensation.

Important results of geometric calibration for multi-sensor

image fusion system are extrinsic parameters in form of homography matrices used for homography transformation of the object plane to the image plane. For each camera a corresponding homography matrix is calculated. These matrices can be used for image registration of images from thermal and low light camera. We implemented such image registration algorithm to confirm accuracy of geometric calibration procedure in multi-sensor image fusion system. Results are given for selected patterns - chessboard with fields made of different emissivity materials. For the final image registration algorithm in surveillance system for object tracking we have chosen multi-resolution image registration algorithm which naturally combines with a pyramidal fusion scheme. The image pyramids which are generated at each time step of image registration algorithm may be reused at the fusion stage so that overall number of calculations that must be performed is greatly reduced.

9250-24, Session 6

Mobile device geo-localization and object visualization in sensor networks

Simon Lemaire, Christoph Bodensteiner, Michael Arens, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

Introduction

In this paper we outline a generic method to visualize selected geo-referenced objects on modern smartphones using augmented reality techniques. We localize camera images using a geo-referenced background model. In addition, the proposed method automatically adapts to all available resources.

Methods

The localization of the mobile device is initially achieved by using common sources like GPS, a WIFI Connection or a mobile network provider. In addition to these methods we accurately localize the on-board camera using a previously acquired background model consisting of geo-localized descriptor points. The used background model is automatically pre-computed using a standard Structure from Motion (SfM) pipeline and stored in a compressed binary form for further processing. Vision based localization is then achieved by matching against this feature database in combination with standard 2-D/3-D pose-determination (PnP) algorithms. We additionally fuse the mobile device inertial measurements for a robust real-time visualization of geo-referenced object visualization using augmented reality techniques. Pose and locations are used to create a virtual environment for proper visualization on the mobile device screen. Given additional object information (e.g. appearance data, images) the augmented reality visualization is further enhances using image matching and optical flow techniques. The application workflow handles all available resources and selects the most valuable localization and visualization methods depending of the available localization and visualization sources. It also handles the mobile device network connections and sends and receives data from a central server application. Consequently the location and pose of the mobile device are stored and visualized on a map on the mobile device and server application. The server application is also used to select objects. The user determines the object location and additionally collects appearance information from the object. This enables a low bandwidth transfer of object information within sensor networks.

Implementation

The mobile application is based on android operation system in combination with OpenCV for android. To handle the object selection a desktop application was developed based on multiple open source libraries like QT, VTK, Bundler and TooN. All relevant calculated data like location and pose of the mobile device are stored in a professional database system (SQLite) on the mobile device as well as on the central server for future reference.

Results

The feasibility of the approach was experimentally validated using modern smartphones (Samsung Galaxy Note 2) in combination with a desktop server application. In order to display the picked object an augmented reality object is shown on the smartphone camera display and additionally Google Maps is used to verify the object position. The location of the mobile device is determined using a geo referenced set of descriptors in combination with location recognition techniques.

Conclusion and outlook

Applications of this approach are widespread and include for instance crisis and disaster management or military applications. Considering the performance and memory size of modern smartphones we are confident to achieve a highly precise and robust geo-localization and visualization of objects seen in smartphone cameras.

9250-25, Session 6

Blurred image recognition based on multi-features fusion

Mengyu Zhu, Zhiguo Cao, Huazhong Univ. of Science and Technology (China)

With the rapid development of image analysis, blurred image recognition is becoming more and more important. One traditional way for blurred image recognition is based on image deblurring and recognition is performed afterward. The point spread function (PSF) is needed for image deblurring, which is unknown in most cases and needs extra estimation. The estimation process involves iterations of the whole image, which is time-consuming. In addition, the different kinds of blur limit the usage of image deblurring. The process for motion blur may not be used for defocus blur generally. The other way is to extract image feature directly for recognition. Although it takes less time and can be used in a more generalized way, it may not perform well in many situations.

In this paper we propose a novel method for blurred image recognition based on the fusion of blur invariant features. Experiment shows that using the method takes less time compared to the image deblurring method and achieves better performance than the method based on generalized image features.

The structure and texture contain different aspects of blurred image information. We choose Histogram of Oriented Gradient (HOG) feature to describe structure information and Local Phase Quantization (LPQ) feature to describe texture information. We also improve LPQ and HOG separately. The original LPQ chooses four different frequency points to calculate STFT, which is inadequate in blurred image description. We improve LPQ feature by changing the way of choosing frequency points in order to make LPQ contain more texture information. The HOG feature is based on the gradient of the image, which may be smoothed by image blur. In other words, the weak gradient should not be taken into consideration. The way to improve the HOG feature is to increase the number of orientation bins and keep only strong gradient for further process. Experiment shows that the improved LPQ and HOG both perform better than original ones in blurred image.

To get a comprehensive description of blurred image from both structure and texture, the two improved invariant features are fused together. Feature fusion improves recognition accuracy by composing features with high complementary and low redundancy. In this paper, Locality-constrained Linear Coding (LLC), a new feature fusion method will be used and the multi-feature based blur invariant feature is constructed, which is used to fully extract information of blurred image and perform image recognition. We test our method on aircraft recognition with different kinds of blur. Experiment shows the proposed method is more accuracy compared to methods with features such as LBP, moments, original LPQ and HOG. In addition, the time taken by our method is significantly less than the method based on image deblurring.

In conclusion, a novel method for blurred image recognition

based on multi-feature fusion is proposed. It improves the original LPQ feature and HOG feature and fuses the features using LLC method, which extracts a thorough description of blurred image. Experiment also shows that the proposed method performs better and takes less time in blurred image recognition.

9250-26, Session 6

Salient region detection in remote sensing images based on integer wavelet transform and color opponent mechanism

Libao Zhang, Jue Zhang, Beijing Normal Univ. (China)

Traditional approaches for detecting targets include classification and segmentation procedures. However, most classification methods require prior knowledge that is inherently difficult to generate and involve time-consuming global searches. To solve these problems, we should be able to pretreat an image to identify salient regions that may contain the target and decrease the data necessary for further classification and detection. To address the overwhelming excess of input, the human visual system (HVS) includes attention mechanisms to select a small subset of possible stimuli for more extensive processing while relegating the remainder to a limited analysis. In this study, we present a salient region detection model for remote sensing images based on the integer wavelet transform and color opponent mechanism., which can be called IWT-COM for short. The IWT is used to extract the orientation image feature. The color opponent mechanism is used to extract the color features. And the difference of Gaussian (DoG) template is employed to compute the saliency value. In addition, a new feature competition strategy is proposed to add different weights to each image feature. Qualitative and quantitative experimental results show that the new algorithm is effective and practical.

9250-27, Session PS

Fixed ground target localization between heterogenous images based on structure pyramid and linear programming techniques

Zhiwen Fang, Zhiguo Cao, Yueming Qin, Wei Li, Huazhong Univ. of Science and Technology (China)

Fixed ground target localization between heterogenous images, such as airborne forward-looking infrared image and reference image, is an important issue widely used in automatic target recognition, automatic tracking system, and navigation. Actually, it is difficult to maintain matching accuracy between heterogenous images due to numerous facts, such as background clutter, partial occlusion and different gray feature.

Generally, there are at least two different fundamental approaches that can be used to localize a fixed ground target between heterogenous images. The first is knowledge-based approach which utilizes the prior knowledge to recognize the target. The second is reference-based approach which detects the target based on references. However, these two approaches only use the information from the targets but ignore the information around the targets in the background, this will lead to the mismatch when the target is small, occluded or similar objects exist.

In this paper, the reference image is generated by projecting 3D building models and the corresponding remote sensing image into the image. The 3D building models and the remote sensing images are both geo-referenced. Therefore, 3D building models and remote sensing images can be projected into the image easily, based on the camera position and attitude. Recently, FAST corner detection is widely used in finding key points in real-time systems for its high efficiency in finding reasonable corner key points. Furthermore, accurate point-pairs obtained by FAST are more than that by Harris, Susan and SIFT between infrared image and reference image through the experiment. Therefore, the FAST key points are adopted in the study to only get the location of the points. Then we propose a descriptor to descript the key points with structure pyramid. Considering the fact that the gray information between the infrared image and reference image is different, the structure information around the key point is mainly to extract. The gradient magnitude and orientation are calculated firstly, then the magnitude contribution of each pixel's neighbors are used to label the pyramid layer number for each pixel. Finally, an image patch centered at the given key points makes up the structure descriptor. Block distance is chosen to measure the similarity between each pair and the nearest point-pairs are the candidate pairs which contain outliers and inliers. We use the affine combination of each point's neighboring points to eliminate the outliers, and the linear programming techniques are used to get the optimum solution efficiently. Then the transform matrix can be calculated easily and target is located through it.

The given target location is labeled in the reference image and the corresponding point would be obtain through transform matrix. Several image sequences including 500 heterogenous image pairs were tested to evaluate the proposed algorithm. For comparing, we also adopt another descriptor, such as SIFT, SURF, and our result is better than those. It demonstrates that the proposed algorithm efficiently improves accuracy of the target location between heterogenous images.

9250-28, Session PS

Remote screening and direct control of the bacterial infection of gardens

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The problem of viruses and bacteria infections in gardens is extremely burning nowadays. That is why, to preserve not only the coming harvest, but in generally to provide stability and growing horticultures the development of new generation analytical techniques for remote express screening vegetative state arrays and direct control of the appropriate infection in case of appearance on the basis of previous surveys are very actually and important. Ervinia amylovora is very dangerous for agriculture. Infection of gardens by it leads to full loss of harvest during several years. Unfortunately, there is still no simple, specific and early detection express methods of this pathogen detection in the. To overcome these drawbacks we proposed the application of such complex of the optical analytical devices as "Floratest" and "Plasmotest" (both produced by V.M. Gluschkov Institute of Cybernetics of the National Academy of Sciences of Ukraine) which is able to control step by step general situation with vegetable state and verify concrete situation with infection. General screening is accomplished on the determination of the intensity of chlorophyll induction (registration of so called Kautsky curve) which testifies about light energy transformation, physiological mechanisms of energy generation, accumulation and effective ways of its realization in cells. The measuring may be done as direct way on the number of individual vegetables and remote screening with transferring registered signal directly in the laboratory. Next step of control connected with the application of the special immune biosensor which is able to determine specific bacteria. It is SPR based immune biosensor which shown the limit of E. amilovora detection in solution equal 0.2 ?g/ml. The overall time of the analysis was 30 min with the duration of one measurement 5 min. The gold surface treated with dodecanthiol showed higher sensitivity to E. amilovora in comparison with bare one. It is necessary to pay attention that the traditional ELISA-method showed the sensitivity to this pathogen equal to 0.5 ?g/ml and overall time of the analysis was much longer than in case of the sensor approach. Moreover, in contrast to the traditional immune chemical methods, application of the SPR based sensor allowed performing analyses, which did not demand use of the specific

antibodies labelled with horseradish peroxidase. These results confirm the advantages of the sensor analysis comparing to the traditional approaches. So, the proposed complex of optical approaches may provide both preliminary direct or remote screening gardening vegetables to have orientation about situation with their physiological state and than directional control of concrete microbial contamination.

9250-29, Session PS

A new technique for the cultivation of the chick embryo in vitro

Mao Ning, Beihang Univ. (China)

The word Radar is the acronym of Radio detection and ranging. Radar is an active instrument, which measures the echo of scattering objects, surfaces and volumes illuminated by an electromagnetic wave internally generated belonging to the microwave portion of the electromagnetic spectrum. It was born just before the second world war for detecting and ranging target for non-civilian scopes. In this case the requested spatial resolution was not so challenging for the technology available that time. The opening of new technological frontiers in the fifties, including the satellites and the space vehicles, demanded a better spatial resolution for application in geosciences remote sensing (RS). Synthetic aperture radar (SAR) technique was invented to overcome resolution restrictions encountered in radar observations from space and generally to improve the spatial resolution of radar images.-The word Radar is the acronym of Radio detection and ranging. Radar is an active instrument, which measures the echo of scattering objects, surfaces and volumes illuminated by an electromagnetic wave internally generated belonging to the microwave portion of the electromagnetic spectrum. It was born just before the second world war for detecting and ranging target for non-civilian scopes. In this case the requested spatial resolution was not so challenging for the technology available that time. The opening of new technological frontiers in the fifties, including the satellites and the space vehicles, demanded a better spatial resolution for application in geosciences remote sensing (RS). Synthetic aperture radar (SAR) technique was invented to overcome resolution restrictions encountered inradar observations from space and generally to improve the spatial resolution of radar images.

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9250-31, Session 6

Hyperspectral data collection for the assessment of target detection algorithms: the Viareggio 2013 trial

Alessandro Rossi, Univ. di Pisa (Italy); Nicola Acito, Accademia navale di Livorno (Italy); Marco Diani, Giovanni Corsini, Univ. di Pisa (Italy); Sergio Ugo de Ceglie, Ctr. Interforze Studi per le Applicazioni Militari (Italy); Aldo Riccobono, Leandro Chiarantini, SELEX ES S.p.A. (Italy)

Hyperspectral sensors mounted on board airborne platforms collect spectral data that can be exploited for several applications, such as classification, target identification, detection of anomalies and changes occurred within multiple acquisitions. In the framework of target detection, the performance assessment of different algorithms in real cases is a very important and critical issue for both the user and the scientific communities. Experimental performance assessment needs the availability of extensive data sets equipped with well-documented ground truth and designed to properly represent different operating scenarios. The lack of public available hyperspectral data collection for target detection algorithms assessment has motivated us in performing an extensive measurement campaign including various operating scenarios. It was organized by CISAM (Centro Interforze Studi e Applicazioni Militari) in cooperation with University of Pisa, Selex-ES and CSSN (Naval Experimentation and Support Centre), and it was conducted in the city of Viareggio, located in the north-west coastline of Tuscany, Italy on 8-9 May, 2013. The airborne Selex-ES hyperspectral sensor SIMGA was adopted for data collection. SIMGA sensor is equipped with two high spectral resolution cameras, operating in the Visible-Near Infrared (VNIR) and in the Short Wave Infrared (SWIR) spectral regions. Hyperspectral data were collected over different sites at morning and afternoon of two subsequent days.

This paper describes the large multi-temporal hyperspectral data collection acquired during the trial. The data were collected to exhaustively assess the performance of anomalous change detection, anomaly detection and spectral matching techniques. Four different sites were set up, representing a complex urban scenario, two parking lots and a coastline/rural area. Part of a selected parking lot site was dedicated to calibration purposes. For the urban and parking lot areas, cars and opaque cloths used to cover cars were used. For the rural scenario, composed of beach and Mediterranean vegetation, polystyrene panels covered by different materials were deployed on the beach, while common clothes were arranged within the vegetation. Generally, the dimension of the deployed targets, in terms of the sensor ground resolution, ranged from a dozen pixels, for largest targets as cars or vans, to less than a pixel, for smallest targets, such as clothes. An extensive ground truth documentation was carried out to give evidence of targets of opportunity.

Experiments to test anomalous change detection techniques were set up changing the geographical position of the deployed materials and vehicles in a urban scenario. Search and rescue operations were simulated to evaluate the performance of anomaly detection algorithms. For this task, common clothes were placed in vegetation areas with structured background. Finally, the reflectance signatures of the objects employed in the campaign were collected on the ground by means of a spectroradiometer in order to test spectral matching algorithms in varying atmospheric and illumination conditions.

The paper also presents preliminary results on the data in order to give examples of the usefulness of the collected data in discussing the advantages and the critical aspects of target detection techniques in different operating scenarios.

9250-32, Session 6

Combining spectral matching and anomalous change detection for target rediscovery in hyperspectral images

Alessandro Rossi, Univ. di Pisa (Italy); Nicola Acito, Accademia navale di Livorno (Italy); Marco Diani, Giovanni Corsini, Univ. di Pisa (Italy)

Multitemporal analysis of airborne HyperSpectral Images (HSIs) is of crucial interest for the surveillance of wide areas. Multiple images of the same scene collected at different times can be exploited to detect changes using anomalous change detection (ACD) techniques. ACD deals with the unsupervised change detection of objects with dimension comparable to the ground sensor resolution. In this context, changes are deletion, insertion or movement of objects within the monitored area.

Among the multitude of applications concerning intelligence gathering, tracking the position of a specific target by means of images from sub-sequent acquisitions over the monitored area is of great interest. Multitemporal hyperspectral imagery, thanks to the high discriminative power of the acquired spectral information, is particularly suitable for such an application. Spectral matching (SM) approaches are effectively adopted in searching for the radiance spectrum of the target within HSIs collected at different times (target rediscovery – TR). The spectrum of the target can be previously measured, or extracted from a previously acquired image integrating auxiliary information provided by further processing or additional imaging sensors.

Depending on both the monitored area and the specific target, TR can be a very challenging task. In fact, it may happen that the target has spectral features similar to those of uninteresting objects in the examined scene and the use of SM techniques without additional information can generate too many misleading detections. This, for instance, can occur when we are interested in tracking a vehicle in a complex scenario, such as the urban one.

In this paper, we propose a new TR strategy aimed at mitigating the number of false alarms encountered in complex scenarios, which combines the potentiality of the SM approach with the unsupervised multitemporal analysis performed by ACD techniques. Particularly, we focus on relocation of moving targets of dimension comparable to the sensor ground resolution in airborne HSIs collected on the same complex area. False alarms mitigation is achieved by exploiting both the target spectral features and the temporal variations of its position in the scene. For this purpose, SM and ACD techniques are properly integrated by searching for the match of the target spectral signature only on those pixels that have undergone changes within multiple acquisitions. Such pixels are detected by resorting to a well-known ACD algorithm designed to be robust to potential mis-registration errors among the multitemporal images.

The proposed scheme is tested on HSIs collected during a measurement campaign conducted by CISAM in conjunction with University of Pisa, CSSN and Selex-ES in Viareggio, Italy in May, 2013. In the experiments, vehicles have been moved among different scenarios, considering more controlled situations, e.g. parking lots, and more dynamic environments, such as an urban scenario in rush hour. In particular, two case

studies are examined, referring to the rediscovery of a car with very distinctive spectral features and, as opposite, of a car with more common features. The results highlight the effectiveness of the fusion of spectral and multitemporal analysis when dealing with TR in complex scenarios.

9250-33, Session 6

Sun-glint false alarm mitigation in a maritime scenario

Alessandro Rossi, Univ. di Pisa (Italy); Aldo Riccobono, SELEX ES S.p.A. (Italy); Stefano Landini, SELEX ES (Italy)

Hyperspectral sensors are gaining ever-increasing importance in the field of avionics systems due to the high information content that they are able to extract from the observed objects on the Earth's surface. This information resides in the high spectral resolution with which these sensors analyze the radiation reflected from objects illuminated by sunlight.

In the maritime environment, hyperspectral sensors can be exploited for detecting rare and small objects, even sub-pixel, given the high contrast between the radiation reflected by the sea water and from the floating objects on the sea surface.

Measurement campaigns were planned in a maritime environment using the Selex-Es SIM-GA hyperspectral sensor installed on avionics platforms. In both the Visible-Near InfraRed (VNIR) and Short Wave InfraRed (SWIR) spectral bands, the contrast between the objects, anomalous with respect to the sea water, and the water itself, is very high. Thus, the detection of the anomalous deployed objects is easily accomplished by means of a local statistical anomaly detection approach. To accomplish this task, Selex-Es recently focused on the development of a local anomaly detection algorithm based on the well-known Reed-Xiaoli (RX) approach, which can run on a processor unit on real-time, furnishing the object location during the reconnaissance flight.

Unfortunately, it has been noticed that the performance of the anomaly detection algorithm is affected by sun-glint. The reflection on the sea surface of the solar radiation produces a high density of alarms, that makes challenging the task of detecting the objects of interest.

In the literature, algorithms proposed to reduce alarms due to sun-glint, are mainly based on two steps. Firstly, potential sun-glint pixels are detected exploiting the NIR spectral channels. Then, sun-glint pixels are recovered relying to a linear stretching of the spatial regions where the phenomenon of the sun-glint has been detected.

In this paper, it is introduced a strategy aimed at discriminating the sun-glint false alarms from the effective alarms related to targets of potential interest. The designed algorithm exploits the entire VNIR and SWIR spectral bands. False alarms due to glint are mitigated performing a local spatio-spectral analysis on each alarm furnished by the anomaly detector. Each potential anomalous pixel is decided to belong to sun-glint or object classes on the basis of a metric of similarity between the pixel itself and the surrounding background. The proposed strategy has been implemented in the real-time processing architecture developed by Selex-ES.

The technique has been tested on hyperspectral images collected during the measurement campaign conducted by CISAM in conjunction with University of Pisa, CSSN and Selex-ES in Viareggio, Italy on 8-9 of May, 2013. Several experiments were carried out, setting up scenarios with small man-made objects deployed on the sea surface, so as to simulate search and rescue operations (e.g., life jackets, buoys, suits).The results have highlighted the effectiveness of the solution in terms of mitigation of false alarms due to glints on maritime scenario.

9250-34, Session 6

Turbulence reduction algorithm in hyperspectral images using four-port imaging spectroradiometer

Florent M. Prel, Stéphane M. Lantagne, Louis M. Moreau, Claude B. Roy, Richard L. Lachance, ABB Analytical Measurement (Canada)

Hyperspectral Imaging Spectroradiometrers (HIS) provide an unmatched advantage for counter measurement, ground truth and infrared characterization.

Turbulences correction is an important challenge especially for pixels on the edge of the observed phenomenon. Typical methods available in the literature to minimize artefacts on the retrieved spectrum are sometimes limited and can introduce undesired bias since they are based on a self-correction of the spectra. However, a four-port spectroradiometer configuration allows turbulence effect reduction without self-correction We describe an automated correction process based on the information provided by the second output port of a four-port imaging FTS. Corrected and uncorrected data will be compared.

9250-35, Session 7

Extraction of incident irradiance from LWIR hyperspectral imagery

Pierre Lahaie, Defence Research and Development Canada, Valcartier (Canada)

Introduction

The atmospheric correction of thermal hyperspectral imagery aims at extracting the temperature and the emissivity of the material imaged by a sensor in the long wave infrared (LWIR) spectral band. It can be divided in two parts: atmospheric compensation (AC) and temperature emissivity separation (TES). TES algorithms require for input the ground leaving radiance and the atmospheric downwelling irradiance [1], [2] and [3]. These inputs are produced by atmospheric compensation of sensor measured radiance. An important difficulty is the estimation from imagery of the atmospheric downwelling irradiance. This paper proposes an approach to perform that task. Equation 1 shows the sensor measured radiance and equation 2 is the ground leaving radiance.

R_s=R_g ?+R_p (1)

R_g=?B(T)+(1-?)L (2)

Where R_s is the radiance measured by the sensor, R_g is the ground leaving radiance, ? is the transmittance, R_p is the path radiance, ? is the emissivity of the pixel's material, B(T) is the blackbody radiation at the temperature T and finally L is the incident downwelling irradiance on the pixel transformed in radiance using the assumption that the material is lambertian. There are often many problems in our way to extract the downwelling irradiance. The first is that since we do not know the characteristics of the image, we have to use assumptions about the nature of some pixels' material and temperatures. We also need some prior data about the atmospheric profiles. One other difficulty also is that very often the spectral response of each pixel is not well characterized.

Algorithm description

The local spectral mean operator can be defined as:

?_? (Q)=1/?? ∫_?^(?+??)?Q(?^')d?' (3)

Starting with the ground emitted radiance we obtain:

?_? (R_g)=1/?? ∫_?^(?+??)??R_g (?^')d?'?=1/?? ∫_?^(?+??)???B(T)+(1-?)Ld?'? (4)

For many materials, the emissivity can be assumed to have has a very slow variation with the wavelength; the blackbody function also has a slow variation with wavelength while the downwelling irradiance is in general composed of a smooth component and a fast varying component due to carbon

dioxide and water vapor. The following approximation is used:

?_? (R_g)~?B(T)+(1-?) ?_? (L) (5)

Subtracting (5) from (2), and isolating L we obtain:

L~(R_g-?_? (R_g))/((1-?))+?_? (L) (6)

In this equation, one very important unknown is removed, the temperature of the material. It is replaced by the assumptions about the emissivity in the image and the spectral average of the atmospheric downwelling irradiance. The algorithm follows from equation (6) and requires the following steps from an operator.

1) Select a number of pixels in the image for which the emissivity is known or can be assumed

a) All the pixels are assumed to have the same emissivity.

b) The assumed emissivity of the pixels shall have very small variations spectrally.

2) Select a spectral interval in terms of the sensor's characteristics (at least 10 bands shall be used)

a) Compute the spectral average for each of the pixels that have been selected in 1

3) Select a suitable atmospheric profile (temperature and humidity), compute the downwelling irradiance using MODTRAN and its local spectral mean using the same spectral interval used in 2.

4) Compute for each pixel the downwelling irradiance and take the mean for each spectral channel of the sensor. This is the downwelling irradiance.

Conclusion

The algorithm has been studied in simulation, to evaluate its robustness to emissivity variations for similar material, for errors in the atmospheric profile and for the sensor noise. It is fairly resistant to noise with the condition that the number of pixels used is high enough depending also on their emissivity. If there are not too many emissivity outliers in the group of selected pixel, the algorithm is not sensitive too sensitive to difference between the mean emissivity of the pixels and the selected emissivity. The error of atmospheric profile is mainly an offset in radiance and the noise can be accounted for by increasing the amount of pixels and by selecting pixels having lower emissivity values.

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9250-37, Session 7

Detection of concealed objects by a multispectral and hyperspectral signatures analysis

Philippe Lagueux, Telops (Canada); Mariusz Kastek, Marcin Kowalski, Henryk Polakowski, Military Univ. of Technology (Poland); Marc-André Gagnon, Telops (Canada)

Public areas are zones at risk against multiple threats including small and simple weapons (such as knives, guns, bombs) that can be concealed under an individual's clothes. Dedicated monitoring systems for the surveillance of such zones attempt to detect dangerous tools with different techniques including the use of infrared cameras operating in various spectral ranges: from the visible to the long wave infrared, and more recently in terahertz spectral range. In order to develop methods and algorithms to detect hidden objects, one needs to characterize the infrared signatures of the interrogated objects.

This paper presents measurements that were conducted to characterize the signatures of dangerous tools hidden under various clothes in varying ambient conditions. The infrared cameras used for the measurements were operating in spectral range 0.6-12.5 μm. An imaging Fourier transform spectroradiometer was also used, operating in the 7.7-11.7 μm spectral range. The analysis of the registered thermograms and hyperspectral data has yielded the thermal signatures for: two types of guns, two types of knives and home-made explosive bombs. The measured thermal signatures will be used in the development of methods and algorithms toward future generations of monitoring systems.

9250-38, Session 7

Non-linear sampling for efficient implementation of the projection-slice synthetic discriminant function filter

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The Projection-Slice Synthetic Discriminant Function Filter has been generated using a sparse sampling technique that utilizes the inherent sprsity of the Projection-Slice theorem. The l1-norm has been utilized to optimize the information contents extracted from the representative class objects. In this work, the results of the usual PSDF without the benefit of convex optimization is compared with the results of the PSDF filter after utilization of convex optimization to assess the merits of the utilization of efficient information reconstruction within the construct of the PSDF.

9250-39, Session 8

Automatic representation of urban terrain models for simulations on the example of VBS2

Dimitri Bulatov, Gisela Häufel, Peter Solbrig, Peter Wernerus, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

Virtual simulations have been on the rise together with the rising progress of rendering engines and graphics hardware. In civil and military applications, where one has to understand the terrain before the plan falls into place, where the situation awareness must be kept at a high level even in a confusing environment, running a mission in simulation before going into the field is already a widely used approach. For example, offensive actions in modern peace-keeping missions have to be quick, firm and precise, especially under the conditions of asymmetric warfare, non-cooperative urban terrain and rapidly developing situations. Going through the mission in simulation can prepare the minds of soldiers and leaders, increase self-confidence and tactical awareness, and finally save lives. Though a simulation in general can never replace training in field, its advantages are obvious: to revert to a simulation helps save costs, be prepared for all possible weather and climatic conditions, play multiple options, and experiment with new, expensive equipment.

Our system of choice is Virtual Battle Space 2, a simulation system created by Bohemia Interactive System. This simulation tool offers a lot of object types that allow a high-quality simulation of typically military missions in urban terrain (persons, animals, vehicles, buildings, etc.), and, moreover, additional tools that provide data exchange with the results of the reconstruction of urban terrain from sensor data. These results are given by the geo-referenced 3D coordinates of the ground points, building vertices, vegetation regions, streets, water areas, and many others. They are obtained by a state-of-the-art algorithm for context-based scene reconstruction.

The context information is very important for the properties of the modeled object, such as collision geometry or modeling damage levels. The texture images are essential for the recognizability of the model.

Thus, the task of the paper is to provide a brief overview over our urban terrain reconstruction algorithm and to demonstrate how the import of large urban scenes can be accomplished in VBS2 within several minutes.

The interaction of the output data of our algorithm and VBS2 is carried out in six steps. First, the ground map is imported by a VBS2-proper development kit Visitor 4 together with a geo-referenced orthophoto. The area of interest, or the world of the simulation, is called map-frame. The second step is to import shape-files for streets; they may be extracted from the sensor data or provided by the public sources available online. The tool needed to prepare streets for VBS2 is called Landbuilder.

The same tool can be used to import water areas (third step), but also vegetation areas like trees and grass (fourth step). However, many parameters, such as types of trees and their probabilities have to be set manually. Therefore, we create source files to import them directly from the results of sensor data evaluation. Several of the parameters mentioned above are set to random or default values, but other parameters, such as positions and heights of trees are more accurate since they stem from the sensor data.

In the fifth step, buildings are imported. Additionally to the 3D-coordinates of the vertices, for every building polygon, we have information about the texture coordinates, the underlying texture image, and also about the building part, such as wall, roof, door or window. These instances are imported fully-automatically with exception of doors and windows. Doors and windows are processed, at the moment, by means of a VBS2-proper tool Oxygen2 for a few important, selected buildings.

As a final step, the mission can be created by filling the area of interest with relevant contents.

9250-40, Session 8

Underwater monitoring experiment using hyperspectral sensor, Lidar and high-resolution satellite imagery

Chan-Su Yang, Korea Institute of Ocean Science & Technology (Korea, Republic of); Sun-Hws Kim, Korea Maritime Univ. (Korea, Republic of)

In general, hyper-spectral sensor, LiDAR and high spatial resolution satellite imagery for underwater monitoring are dependent on water clarity or water transparency that can be measured using a Secchi disk or satellite ocean color data. Since optical properties in the sea waters of South Korea are influenced mainly by a strong tide and oceanic currents, diurnal, daily and seasonal variations of water transparency were investigated from the Geostationary Ocean Color Imager (GOCI) satellite imagery using the semi-analytical algorithm based on the vertical diffuse attenuation and beam attenuation coefficients. The satellite-based Secchi depth (ZSD) analysis showed the applicability of hyper-spectral sensor, LiDAR and optical satellite, determined by the location connected with the local distribution of case 1 and 2 waters.

The northwest and southeast coastal areas of Jeju Island are selected as test sites for a combined underwater experiment, because those areas represent case 2 and 1 waters, respectively. Our experiments are as follows: 1. inter-comparison of water depths obtained from three different sensors; 2. detection of water plants attached to an underwater rock; 3. discrimination of underwater targets installed on the ocean floor.

Three sensors used here are the CASI-1500 (Wide?Array Airborne Hyperspectral VNIR Imager (0.38 – 1.05 microns), the Coastal Zone Mapping and Imaging Lidar (CZMIL) and Korean Multi-purpose Satellite-3 (KOMPSAT-3) with 2.8 meter multi-spectral resolution.

The experimental results were affected by water clarity and surface condition, and multi- and hyper-spectral sensors were effective in lower depth. In the shallow region, hyper-spectral sensor revealed a target on the seafloor along with LiDAR. More details will be provided on the conference.

9250-41, Session 8

Wideband radar imaging for space debris based on direct IF sampling signals

Yang Liu, Zengping Chen, Na Li, Shiyou Xu, National Univ. of Defense Technology (China)

Space debris is a serious security problem in space environment, since its high speed may produce potential collision risk and cause disaster to operational spacecrafts. The consequence of collision depends on the size of debris. Therefore, the shape estimation of space debris is an important task. The imaging for the space debris by the use of the wideband radar is an approach to access to the extract the dimensional and structural feature. Thus, this paper investigates a imaging method for space debris by wideband radar.

Generally speaking, in traditional wideband radar imaging, a linear frequency modulation (LFM) signal is transmitted, and then the echo is dechirped to decrease the receiver bandwidth. A well-focused image can be achieved by using appropriate translational motion compensation and image reconstruction algorithm. The motion compensation constitutes of two steps: range alignment and phase compensation. Range alignment of dechirped echoes is often realized based on the envelope correlation, under the assumption that the target is rigid-body one and flies stably. However, the space debris rotates around its principal axis at a certain angular speed. In that case, the correlation of the adjacent high range resolution profile (HRRP) is undermined and the motion compensation method for dechirped echoes is invalid.

With the development of analog-to-digital converter (ADC), direct intermediate frequency (IF) sampling for wideband radar signals becomes realistic and widly in practical applications. The IF sampling technique has the advantage in maintaining the coherence of echo pulse. Based on the coherent property, the translational motion compensation can be implemented by taking in coherent method based on the motion track of the target, which eliminates the negative influence caused by the spinning. As a consequence, a wideband imaging method based on IF sampling signals is proposed.

The proposed approach are mainly constitute of three steps. Firstly, the IF sampling wideband signal model of the space debris is founded and the coherence of the echo pulses sampled directly in IF is analyzed. Secondly, the accurate translational motion parameters?ranges and velocity, of the target are estimated from the observations of the radar. Due to the radar system error, the ranges and velocity of the target measured by radar are not unbiased. Therefore, the polynomial fitting method is used to obtain the accurate translation motion track of the target. Then, after certain translational motion compensation in frequency domain, the rotational component will be only contained in instantaneous range function. Finally, the improved back prejection transform (BPT) method is used for the image reconstruction, which transforms the echo from range-time domain to the scatterer distribution plane by coherent cumulation. A high resolution image of the space debris can be obtained without side lobe peaks.

Simulation results confirm the effectiveness of the method proposed in this paper. For generality, the imaging model of the simulated space debris is set to a 2-D plane. The target consists of three scatterers with isometric intensity and rotates with a constant velocity of ?=10ϖ rad/s. The carrier frequency and bandwidth are 10GHz and 2GHz, respectively. The range resolution is 0.075m ,which is smaller than the size of the target. A well focused image is obtained by utilizing the proposed motion compensation and improved BPT methods. When the improved BPT used in the image reconstruction is replaced by general Radon transform (GRT), the resolution of the image will descend.

Conference 9251A: Technologies for Optical Countermeasures

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9251-1, Session 1

High-power laser research *(Keynote Presentation)*

Don Seeley, U.S. Army Space and Missile Defense Command (United States); Lawrence E. Grimes, Air Force Research Lab. (United States)

No Abstract Available

9251-2, Session 1

Requirements for laser countermeasures against imaging seekers *(Keynote Presentation)*

William D. Caplan, NIRCM (Netherlands)

Conventional anti-aircraft infrared seekers all operate on the principle of detecting the position of a IR source (target) by modulating the FOV to encode the track of the target. This is a fundamental susceptibility of this class of seeker that renders them vulnerable to laser jamming with DIRCM. What they need are two things: modulation techniqes and sufficient power for a J/S of 100 – 1000. There are several DIRCM systems available that meet these requirements and provide a high degree of protection against reticle seekers.

The latest generation of IR seekers use imaging technology that discriminates the target position in a fundamentally different manner. This class of seeker is not susceptible to DIRCM jamming. This paper examines the effectiveness of laser jamming against imaging seekers to derive requirements for laser countermeasures against imaging seekers

Since reticle seekers are constructed with optical components that define the modulation of point sources in the FOV, designing countermeasure modulation techniques against them is straightforward once a example of the model is obtained for laboratory testing.

Imaging seekers present a further complication in that the image processing techniques that can be used to track the target and reject countermeasures are entirely defined by the on-board software of the seeker. It is practically impossible to know in advance what algorithms are used, especially considering that software changes are easy to implement even after the particular models are in service.

Imaging seekers may be vulnerable to higher power laser jamming. The effect of laser dazzle against imagers as it is published in numerous studies appears to degrade the image quality. However, actual scatter amplitude levels can be modelled and it can be shown that usable information is still available to the seeker under dazzle.

If neither decoy expendables nor dazzle lasers are expected to be effective against imaging seekers then the logical next step is to increase the laser power to produce damage. Estimates are provided to indicate the laser power levels that would be required against an imaging seeker focal plane. Although it is possible to design seekers that are hardened against laser damage, it is not clear that such designs are practical.

9251-3, Session 2

Future DIRCM system-concepts *(Invited Paper)*

Helge Bürsing, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

No Abstract Available

9251-4, Session 2

The next generation in aircraft protection against advanced MANPADS *(Invited Paper)*

Stuart N. Chapman, Selex ES (United Kingdom)

This paper discusses the advanced and novel technologies and underlying systems capabilities that Selex ES has applied during the development, test and evaluation of the twin head Miysis DIRCM System in order to ensure that it provides the requisite levels of protection against the latest, sophisticated all-aspect IR MANPADS. The importance of key performance parameters, including the fundamental need for “near-spherical” coverage, rapid time to energy-on-target, laser tracking performance and radiant intensity on seeker dome is covered.

It also addresses the approach necessary to ensure that the equipment is suited to all air platforms from the very smallest helicopters to large transports, while also ensuring that it achieves an inherent high reliability and an ease of manufacture and repair such that a step change in through-life cost in comparison to previous generation systems can be achieved.

The benefits and issues associated with open architecture design are also considered.

Finally, the need for extensive test and evaluation at every stage, including simulation, laboratory testing, platform and target dynamic testing in a System Integration Laboratory (SIL), flight trial, missile live-fire, environmental testing and reliability testing is also described, and some results from recent flight and livefire tests are provided.

9251-5, Session 2

ELBIT MUSIC system *(Invited Paper)*

Armona Brandl, David Yoskovich, Elbit Systems Ltd. (Israel)

Elop is a pioneer in the field of Directional Infra-Red Countermeasure (DIRCM) systems, designed to protect aircraft from heat seeking ground to air missiles, also known as MANPADS (Man Portable Air Defense Systems). Elbit’s MUlti Spectral Infrared Countermeasure (MUSICTM) systems are a family of DIRCM solutions designed to protect all types of aircraft, large and small. These systems integrate a patented advanced fiber laser technology together with a high rate, image processing thermal camera and a compact, highly dynamic, large Field of Regard mirror turret to provide effective, reliable and affordable protection to all types of aircraft and under all operational conditions. The systems are built around open architecture, can easily be integrated on any type of rotor or fixed wing aircraft with either UV or IR missile warning systems, are adaptable to threat evolution, and provide highest reliability and low Life Cycle Costs (LCC). The MUSICTM systems have undergone extensive tests and evaluation at every stage, including simulation, laboratory testing, platform and target dynamic testing in Integration Laboratories, flight

tests, special field tests, environmental and reliability testing. The MUSICTM family has been extensively and successfully tested outside of Israel and is under full scale production for numerous customers around the world – for a large variety of military, VIP and commercial aircraft.

9251-6, Session 3

Ultraviolet signature collection of airborne platforms and decoy flare countermeasures

Leon Smith, Mark A. Richardson, Cranfield Univ. (United Kingdom); Richard Ayling, Chemring Countermeasures Ltd. (United Kingdom)

With the improvement in missile counter-countermeasure techniques comes the requirement to determine the effectiveness of currently employed decoy flare countermeasure systems. In the past simulations of engagements between missile systems and airborne platforms have been modelled using CounterSim, an engagement environment simulation tool developed by Chemring Countermeasures Ltd. In order to progress with the simulation of modern missile systems that utilise a UV guard channel, a firm understanding of the emission and reflection characteristics of targets and countermeasures is required.

In this paper the theory of UV emission from Magnesium/Teflon/Viton (MTV) based flares is discussed, along with signature collection using UV spectral equipment. Also discussed are the reflection characteristics from likely airborne targets in the near UV region of the EM spectrum, supported by spectral reflection measurements carried out by the author.

9251-7, Session 4

Lasers in electronic warfare *(Invited Paper)*

Gerald C. Manke II, Naval Surface Warfare Ctr. Crane Div. (United States)

No Abstract Available

9251-9, Session 4

Incoherent aperture beam combining of quantum cascade lasers

Katrin Dahl, Michael Raab, Hans Dieter Tholl, Diehl BGT Defence GmbH & Co. KG (Germany)

High power lasers emitting light within in the atmospheric window are of particular interest for numerous defence applications, e.g. infrared countermeasures. If a laser source with the required characteristics, i.e. power, beam quality, etc., is not available a set of lasers can be used instead of one single laser source. The light of these lasers can be combined by several techniques, e.g. spectral beam combining, polarization beam combining, or incoherent aperture beam combining. Each technique has its advantages and drawbacks. Polarization beam combining is limited to only two laser beams. Spectral beam combining demands light of different wavelength. The technique of incoherent aperture beam combining offers the greatest flexibility of the foresaid techniques in terms of properties of the laser sources. For incoherent aperture beam combining the laser beams are arranged side by side on the aperture of the (multi-) laser system and combine in the far field. The technique is neither limited to any number of lasers nor to any laser characteristics. We investigated incoherent aperture beam combining of quantum cascade laser beams in experiment and simulations at different distances from the laser aperture. We present results of combining laser sources of different wavelengths and demonstrate advantages of diverse beam arrangements.

9251-12, Session 4

High-power mid-Infrared continuous-wave optical parametric oscillator pumped by fiber lasers

Xiaojun Xu, Xiao Li, Lei Liu, Yaping Shang, National Univ. of Defense Technology (China)

3~5um Mid-infrared laser has very important applications in fields of trace gas detection, spectroscopy analysis, remote sensing, medical treatment, and also in laser radar and infrared countermeasure. Optical parametric oscillator (OPO) is the most efficient way to generate lasers in this wavelength range, thus it has attracted the eyes of many people. In this paper, the recent development of mid-infrared OPO was briefly overviewed. We also gave a detailed introduction on our recent work, maximum idler output power of 34.2W at the center wavelength of 3.35um. It is worth mentioning that the pump source?which is a kilowatt quasi single-frequency narrow line-width fiber laser was self-developed by our group. To our knowledge, this idler output power is the world highest public reporting record at present. Based on the current status of research, some solutions were proposed in order to achieve compact higher power, narrower line-width mid-infrared OPO with larger tuning range.

9251-10, Session 5

All fiber-based ultra-short chirped pulse amplification laser operating at 2?m wavelengths based on thulium-doped germanate active fibers *(Invited Paper)*

Arturo Chavez-Pirson, NP Photonics, Inc. (United States)

Mid-infrared sources are a key enabling technology for various applications such as remote chemical sensing, defense communications and countermeasures, and bio-photonic diagnostics and therapeutics. Ultra-short pulse (USP) lasers—where the laser pulse duration is less than a picosecond—are a unique class of lasers that induce a variety of compelling phenomena as a result of their exceedingly short pulse widths. An all-fiber approach to generate a high power (multi-watt), single mode beam (M2 < 2) with high peak power and ultra-short pulse width (< 1 ps) has significant advantages in terms of reliability (no moving parts or alignment), room temperature operation, size, weight, and power efficiency; this is expected to have a major impact on many applications, such as, for example, infrared countermeasures (IRCM) where a suitable ultra-short pulse laser operating near 2?m is needed as a laser source and/or to generate mid-IR (3?m - 5?m) super-continuum in a nonlinear optical fiber. Our USP laser system is based on a chirped pulse amplification architecture, and operates at 1917nm wavelength. It consists of a short pulse (< 1 ps) mode-locked fiber laser oscillator based on carbon nanotube saturable absorber, pulse picking/stretching fibers, low distortion fiber amplifier, and compressing optics to re-constitute the ultra-short pulse - with much higher peak power and energy. For peak and average power scaling above the 100 micro-joule level, we have developed novel thulium (Tm)-doped germanate glass large mode area fibers for use in a high efficiency, high power, low B-integral, short-length, fiber amplifier. To date, we have obtained < 800 fs pulses from the all-fiber mode-locked laser oscillator, and achieved over 9W of average power and 100's of micro-joule level pulse energies from a Tm-doped germanate fiber amplifier. We will review and discuss our progress towards further scaling of peak and average powers, and the development of a compact prototype system suitable for field applications.

9251-11, Session 5

2 μm and mid-IR fiber-laser-based sources for OCM *(Invited Paper)*

Christelle Kieleck, Antoine Berrou, Christian Kneis, Brenda M. Donelan, Marc Eichhorn, Institut Franco-Allemand de Recherches de Saint-Louis (France)

The paper describes new laser sources and non linear conversion setups for 2 μm and mid-IR generation based on fiber technologies. Especially for jamming heat-seeking missiles, these novel designs allow to propose future compact, efficient and integrable laser systems. The specialty of the ISL technology lies in the use of a single 2 μm fiber laser oscillator, which delivers the full output power, attached to an optical parametric oscillator or a nonlinear fiber. No multi-stage amplifiers (at 2 ?m or 1.55 ?m) are necessary.

The best results achieved in continuous-wave (CW), Q-switched (QS) and modelocked (ML) regimes with fiber lasers based on Tm3+-doped and Tm3+;Ho3+-codoped fiber are presented.

Up to 70 W of average power was achieved around 2 μm with a Tm3+-doped fiber in CW regime. In ML regimes at a repetition rate of 60 MHz, 30 W of average power was reached. In QS regime, up to 36 W of average power was generated around 1985 μm with a Tm3+-doped fiber and the repetition rate can be varied. For example, at 50 kHz, the pulse duration was around 26 ns at the maximum output power. With a Tm3+;Ho3+-codoped fiber, up to 25 W of average power was obtained around 2070 nm and the repetition rate can also vary. For example at 50 kHz, the pulse duration was around 50 ns at the maximum output power. The M? was estimated to be less than 1.2.

The emission from QS fiber lasers was used to directly pump OPGaAs and ZGP OPOs. In band II, up to 6.5 W of averaged power was obtained from a ZGP OPO pumped by a Tm3+-doped fiber laser. At 40 kHz repetition rate, the pulse duration was around 65 ns at the maximum output power. For 2 W of averaged output power, the M? of the signal beam was estimated to be less than 2.1 and less than 2.4 for the idler beam.

With a 2.09 ?m Q-switched Tm3+;Ho3+:silica fiber laser pump source, up to 2.2 W of average output power was achieved at 40 kHz repetition rate with a plane-plane OP-GaAs OPO-cavity.

Using a modelocked pump, an overall supercontinuum power of up to 1080 mW from a pump power of 3 W incident onto a ZBLAN fiber at an injection efficiency of 50?60% was achieved. The SC extends to beyond 3.6 ?m. This corresponds to over 216 mW in the mid-IR supercontinuum above 2340 nm and to an overall supercontinuum power efficiency of ~ 3.3% with respect to the thulium laser pump diodes.

ISL is currently improving those results.

9251-13, Session 6

Laser source with high pulse energy at 3-5 μm and 8-12 μm based on nonlinear conversion in ZnGeP2 *(Invited Paper)*

Espen Lippert, Helge Fonnum, Magnus W. Haakestad, Norwegian Defence Research Establishment (Norway)

Development of infrared laser sources in the 3-5 ?m and 8-12 ?m spectral bands is motivated by several applications including laser-tissue interactions in medicine and optical remote sensing. Such laser sources can be based on nonlinear optical conversion of radiation from Ho lasers. Zinc germanium phosphide (ZGP) is an attractive nonlinear material due to its high nonlinear coefficient, high damage threshold, good transmission in the 2-10 μm range, and high thermal conductivity.

A way to obtain good beam quality at high pulse energies is the master-oscillator-power-amplifier (MOPA) approach, where an optical parametric oscillator (OPO) is pumped with a low-energy pump beam and optimized for producing pulses with good beam quality. The output from the master OPO is then used as a seed in an optical parametric amplifier (OPA). The beam quality of the seed pulses can be maintained in the OPA by careful optimization of the setup.

We here demonstrate a ZGP-based MOPA with 0.2 J pulse energy in the 3-5 μm region, with a beam quality M2 =3. The MOPA is pumped by 0.5 J pulses at 2.05 μm, with 15 ns duration, from a cryogenically-cooled fiber laser pumped Ho:YLF oscillator operating at a repetition rate of 1 Hz.

Extensive numerical simulations using in-house simulation software for lasers and nonlinear interactions have been carried out to investigate how the system can be optimized for generating radiation in the long-wave infrared (8-12 μm) region. The simulations show that 70 mJ pulse energy at 8 μm wavelength, with M2=2 could be achievable by combining type I and type II phase-matching stages in the power amplifier. After the first type II amplifier stage the signal at 2.75 μm is separated from the idler to avoid back-conversion in a second type II amplifier stage, and in the last type I stage the signal from the first stage is recombined and used as a pump thus converting from energy 2.75 μm to 8 μm.

9251-15, Session 6

Efficiency-enhanced mid-wave infrared beam generation at 3.8 um with a seeded optical parametric generator

Ziya G. Figen, TÜBITAK BILGEM ILTAREN (Turkey)

In this paper, we model the performance of a device with a simple architecture for high-power mid-wave infrared beam generation at a wavelength of 3.8 microns. The device is a seeded idler efficiency-enhanced optical parametric generator (IEE-OPG) based on an aperiodically poled MgO-doped LiNbO3 (APMgLN) grating pumped by a high-repetition rate nanosecond-pulsed 1064-nm laser and seeded by a low-power 1478-nm distributed feedback diode laser. In the IEE-OPG, two optical parametric amplification (OPA) processes, OPA-1 and OPA-2, are simultaneously phase matched in a single APMgLN grating. The signal at 1478 nm is amplified and the idler at 3800 nm is generated as a result of OPA-1, the signal acts as the pump for OPA-2 and the conversion efficiency of the idler is enhanced as a result of OPA-2. Also, a difference-frequency beam at 2418 nm is generated.

We characterized the device performance using a realistic model that takes the diffraction of the beams into account. We designed multiple aperiodic gratings with varying relative strengths of OPA-1 and OPA-2. We note that the relative strength of these processes is calculated using the ratio of the heights of the peaks in the Fourier transform of the aperiodic grating function which are located at the phase-mismatches corresponding to OPA-1 and OPA-2. For various crystal lengths, optimum relative strengths of the two processes and input pump power levels for achieving the maximum mid-wave infrared conversion efficiency and output power are determined.

We used an aperiodic grating design method that allows simultaneous phase matching of any two arbitrary nonlinear processes and also free adjustment of the relative strength of them [1]. This method relies on generating an aperiodic grating structure that has domain walls located at the zeros of the summation of two cosine functions. We previously used this method for designing aperiodic gratings for a red beam generating seeded OPG whose parameters are optimized for maximum red beam efficiency or power [2].

Efficiency-enhanced mid-wave infrared beam generating optical parametric oscillators (OPOs) based on APMgLN gratings designed with the method mentioned above were reported before [3]. However, no attempt was made for the optimization of the relative strengths of the simultaneously phase-matched processes in these devices. Furthermore, OPGs have some advantages over OPOs in terms of their output stability, especially in environments where the mechanical stability is a stringent requirement. Also they do not require

surface coatings which make them more suitable for high power applications. Our model calculations show that it is possible to reach and exceed the mid-wave infrared conversion efficiencies of these OPOs by correctly choosing the design parameters of the seeded OPGs based on relatively long APMgLN gratings.

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9251-16, Session 6

Temperature-stable lithium niobate electro-optic Q-switch for improved cold performance

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Lithium niobate (LN) is commonly used as an electro optic (EO) Q-switch material in infrared targeting lasers because of its relatively low voltage requirements and low cost compared to other crystals. A common challenge is maintaining good performance at the sub-freezing temperatures often experienced during flight. Dropping to low temperature causes a pyro-electric charge buildup on the optical faces that leads to birefringence non-uniformity and depolarization resulting in poor hold-off and premature lasing. The most common solution has been to use radioactive americium to ionize the air around the crystal and bleed off the charge, but the radioactive material requires special handling and disposal requirements that are problematic. We have developed a superior solution that is now being implemented by multiple defense system suppliers. By applying a low level thermo-chemical reduction to the LN crystal optical faces we induce a small conductivity that allows pyro-charges to dissipate. As the material gets more heavily treated, the capacity to dissipate charges improves, but the corresponding optical absorption also increases, causing insertion loss. Even though typical high gain targeting laser systems can tolerate a few percent loss the thermo-chemical processing needs to be carefully optimized. We describe the results of our process optimization to minimize the insertion loss while still giving effective charge dissipation. Treatment is performed at temperatures below 500°C and a conductivity layer less than 0.5mm in depth is created that is uniform across the optical aperture. Because the conductivity is thermally activated, the charge dissipation is less effective at low temperature, and characterization needs to be performed at cold temperatures. The trade-off between optical insertion loss and potential depolarization due to low temperature operation will be detailed and we also report experimental results on the temperature dependence of the dissipation time and the optical loss.

9251-17, Session 7

Optical countermeasures against human operators *(Invited Paper)*

Alexander Toet, TNO Defence, Security and Safety (Netherlands)

Despite the advent of remotely operated and autonomous targeting systems, human (direct) vision is still critical for the successful performance of many tasks on the battlefield. There are for instance many weapon systems in which a human operator acquires a target, tracks it and designates it. Successful piloting of aerial and surface vehicles also still depends critically on human vision. Optical countermeasures can be deployed to deny operators the possibility to successfully fulfill their tasks. Depending on their power, spatio-temporal and spectral characteristics, high intensity light sources have the potential to generate a variety of disturbing visual effects, ranging from short-term disruption to lasting eye damage. High intensity light sources therefore offer a simple and cost-effective method of defence. Here we will describe the full range of different effects that result from stimulation of the human visual system with high intensity (visible) light, and their associated potential operational impact. Of practical use are flash blindness, where an intense flash of light produces a temporary "blind-spot" in (part of) the visual field, flicker distraction, where strong intensity and/or color changes at a discomfortable frequency are produced, and disability glare where a source of light leads to contrast reduction. A variety of devices that can effectively induce these disturbing visual effects is currently available such as lasers, high intensity search beams and flares. In this paper we will report on the actual effect of the use of these countermeasures on human vision.

We performed a range of laboratory experiments and field trials to investigate the operational impact of optical countermeasures against human operators. In the laboratory we investigated the effects of (1) brief high intensity flash insults on pilot performance during simulated pursuit flights and of (2) chromatic flicker on driving, search and tracking tasks. In an actual in-flight validation study we investigated the effects of several broadband high intensity light sources and a laser on pilot vision at night. Here we report the results of these studies and discuss their practical implications.

9251-18, Session 7

Modeling of the over-exposed pixel area of CCD cameras caused by laser dazzling

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A simple model has been developed and implemented in Matlab code, predicting the over-exposed pixel area of cameras caused by laser dazzling. Inputs of this model are the laser irradiance on the front optics of the camera, the Point Spread Function (PSF) of the used optics, the integration time of the camera, and camera sensor specifications like pixel size, quantum efficiency and full well capacity. Effects of the read-out circuit of the camera are not incorporated. The model was evaluated with laser dazzle experiments on a CCD camera using a 532 nm CW laser dazzler and shows good agreement. For relatively low laser irradiance the model predicts the over-exposed laser spot area quite accurately and shows the 1/3 power dependency of spot diameter on laser irradiance, caused by the PSF as demonstrated before for IR cameras [Schleijpen, Proc. SPIE Vol. 6543, 2007]. For higher laser power levels the laser induced spot diameter increases more rapidly than predicted, which probably can be attributed to scatter effects in the camera. Some first attempts to model scatter contributions, using a simple scatter power function, show good resemblance with experiments. Using this model, a tool is available which can be used to assess the performance of observation sensor systems while they are subjected to laser countermeasures.

9251-19, Session 7

Towards the implementation of a spectral data base for the detection of biological warfare agents

Mariachiara Carestia, Roberto Pizzoferrato, Michela

Gelfusa, Orlando Cenciarelli, Fabrizio D'Amico, Andrea Malizia, David Scarpellini, Univ. degli Studi di Roma "Tor Vergata" (Italy); Andrea Murari, Consoezio RFX-Associazioe EURATOM ENEA per la Fusione (Italy); Jeus Vega, Asociación EURATOM/CIEMAT para Fusión. (Spain); Pasquale Gaudio, Univ. degli Studi di Roma "Tor Vergata" (Italy)

Different optical measurement techniques can be applied for biological agent warning, detection and identification [1].

The threat represented by the deliberate use of pathogen (bacteria, toxins, viruses...) is a great concern both from the military and civilian point of view [2]. Until now only point detection systems are applicable [3] in monitoring campaigns to prevent the effects of biological warfare agents release. The biological and non-biological assays employed to detect and identify those agents still depend on sampling procedures and, in addition, most of them are time consuming and require well trained personnel to be performed.

For this reason, stand-off detection and identification of biological aerosols released in an open environment, represent a big challenge and the main goal to achieve.

Previous studies show that biological samples can be analyzed by means of several optical techniques, covering a broad region of the electromagnetic spectrum. These approaches include Infrared Depolarization, Long Wave Infrared differential scattering, UV-laser induced fluorescence. Each technique provides different information about the biological agent under investigation and shows particular strengths and weaknesses in detecting the atmospheric dispersion of biological agents [1].

In this work, we intend to investigate the capability of discriminating between different biological warfare agent simulants (BWA-S) through the analysis of the optical emission spectra. To accomplish this task, a deep knowledge of fluorescence features with different boundary conditions is required, in order to create a database of comparable spectral fingerprints.

We have performed photoluminescence measurements, through a laboratory setup with a standard UV lamp source, on some of the most commonly used biological warfare agent simulants (Bacillus subtilis, Bacillus globigii, Bacillus thuringensis, Escherichia coli and others). We paid particular attention to find an adequate level of standardization in the preparation of the biological samples (growing conditions, washing procedure etc.) and relevant physiochemical parameters were evaluated.

Preliminary results showed that significant differences can be appreciated among BWAs simulant emission spectra, but these differences also seem to depend on the sample preparation method.

Specifically, the significant contribution to the optical signal coming from the supernatant fraction of a suspension of unwashed spores or vegetative cells has been identified, confirming previous results from Hill and colleagues [4]. These data underline the needs for an accurate characterization of the sample in order to create a valid spectral fingerprints database.

Moreover, nowadays, data from literature show significant variability in the selection and preparation of the biological samples. The selection criteria are strictly connected to the variability of the results obtained with similar optical techniques, enlightening another relevant issue which has to be faced in order to minimize false positive and false negative results when using stand-off techniques for the detection of biological aerosols.

This work represents a first step towards the implementation of a spectral database and a laser for the stand off detection of biological agents.

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9251-20, Session 7

Further comparison of MODTRAN®5 to measured data in the UV band

Leon Smith, Mark A. Richardson, Cranfield Univ. (United Kingdom); Richard Ayling, Nick Barlow, Chemring Countermeasures Ltd. (United Kingdom)

The ability to accurately model background radiation from the sun is important in understanding the operation of missile systems with ultraviolet (UV) guard channels. In theory a missile system's UV channel detects a target's silhouette, caused by its 'negative contrast' with respect to background UV radiation. The variation in background levels of UV will therefore have an effect on the operability of a missile system that utilises a UV channel.

In this paper an update on the measurement and comparison of background UV-A radiation to data produced by MODTRAN®5 (MODerate resolution atmospheric TRANsmission) is given. In the past surface flux and radiance data calculated using MODTRAN®5 has been compared to data from the WOUDC (World Ozone and Ultraviolet Data Centre) archive, and measurements taken by the author at the Defence Academy of the UK. With the aid of power calibrated spectral measurement equipment, new measurements have been made and compared with the magnitudes of radiance produced by MODTRAN®5, including measurements made throughout both winter and summer months. Also discussed are the effects of scattering and absorption by different cloud types on the amount of radiation observed at the Earth's surface.

9251-14, Session 8

Aircraft vulnerability analysis by modelling and simulation *(Invited Paper)*

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No Abstract Available

9251-21, Session 8

ELT-572(v)2 DIRCM: simulation, system design and DT&E process to protect ItAF Platforms against ManPADS *(Invited Paper)*

Luigi Ideo, Giorgio Mazzi, Andrea Usai, Valter Bonori, Elettronica S.p.A. (Italy); Fabio Togna, Giancarlo Borriello, Aeronautica Militare Italiana (Italy); Antonio Tafuto, Elettronica S.p.A. (Italy); Mirko Cresti, Intecs S.p.A (Italy); Emiliano Dente, Skytechnology (Italy)

In this paper authors provide a description of the currently deployed Man Portable Air Defense Systems (MANPADS) heat-seeking missiles. Principles of IR seeking and Aircraft signatures are shortly described.

Basic information are listed on currently designed Infra Red Counter Measure Systems, intended to protect Aircrafts against

MANPADS.

Authors provide an overview on ELT 572(v)2 DIRCM Program, funded by Italian Air Force, currently in low rate production phase. Description of the Design and Development phase, completed in Elettronica SpA in 2013, is reported.

Verification and Validation (V&V) Activities on ELT 572(v)2 DIRCM, jointly performed by Elettronica Spa and Italian Airforce Flight Test Centre, are shortly described. A summary of tests, validation activities and some unclassified results are discussed.

Platform Installation Programs, using the low rate production units from ELT 572(v)2 DIRCM Program, are finally listed.

9251-22, Session 8

Modelling a man-portable air-defence (MANPAD) system with a rosette scan two-colour infrared (IR) and ultraviolet (UV) seeker

Devinder Kumar, Leon Smith, Mark A. Richardson, Cranfield Univ. (United Kingdom); Richard Ayling, Nick Barlow, Chemring Countermeasures Ltd. (United Kingdom)

Successful engineering of spectral airborne IR countermeasures (CM) against existing two colour IR seekers has encouraged missile counter-countermeasure (CCM) designers to utilise the silhouette signature of an aircraft in the UV as a means of distinguishing between a true target and a flare CM. In this paper we describe the modelling process of a dual band IR and UV rosette scan seeker using CounterSim, a missile engagement and countermeasure simulation software package developed by Chemring Countermeasures Ltd. Results are shown from various simulated engagements of the dual band MANPAD with a C-130 Hercules modelled by Chemring Countermeasures. These results have been used to estimate the aircrafts' vulnerability to this MANPAD threat. A discussion on possible future optical countermeasures against dual band IR-UV seekers is given in conclusion to the simulation results.

Conference 9251B: High-Power Lasers 2014: Technology and Systems

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9251-30, Session 10

The mobile and stationary laser weapon demonstrators of Rheinmetall Waffe Munition *(Invited Paper)*

Klaus Ludewigt, Thomas Riesbeck, Thomas Baumgärtel, Jürgen Schmitz, Markus Jung, Alexander Graf, Rheinmetall Waffe Munition GmbH (Germany)

Over the past few years Rheinmetall Waffe Munition has successfully developed, realized and tested a variety of versatile high energy laser (HEL) weapon systems for different applications such as C-RAM, air-defence and UXO clearing scenarios. By employing beam superposition technology and a modular laser weapon concept, the total optical power could be increased successively on multiple platforms. This does not only include stationary weapon platforms but also mobile vehicles equipped with a high energy laser effector. Within our contribution we will give an overview about the most recent development stages of Rheinmetall's high energy laser weapon program.

We will present three different HEL demonstrators: the 5 kW class Mobile HEL Effector Track V integrated in a M113 tank, the 20 kW class Mobile HEL Effector Wheel XX integrated in a multirole armoured vehicle GTK Boxer 4x4 and the 50 kW class Mobile HEL Effector Container L integrated in a reinforced Container carried by a 8x8 truck.

Beside the integration of HEL effectors in mobile platforms Rheinmetall increased the capability of the 30 kW Laser Weapon Station, towards defeating saturated attacks of RAM targets and unmanned aerial vehicles.

All HEL demonstrators have been tested in a firing campaign at the Rheinmetall testing centre in Switzerland. Major results of these tests will be presented. A prospect on the next development steps towards a HEL weapon by Rheinmetall will be given.

9251-31, Session 10

Ultrashort pulsed laser technology development program *(Invited Paper)*

Gerald C. Manke II, Naval Surface Warfare Ctr. Crane Div. (United States)

The Department of Navy has been pursuing a technology development program for advanced, all-fiber, Ultra Short Pulsed Laser (USPL) systems via Small Business Innovative Research (SBIR) programs. Multiple topics have been published to promote and fund research that encompasses every critical component of a standard USPL system and enable the demonstration of mJ/pulse class systems with an all fiber architecture. This presentation will summarize published topics and funded programs.

9251-33, Session 10

Broadband hybrid IR laser system emitting within 2.5-16.57 micron

Andrey A. Ionin, Igor Kinyaevskii, Yurii M. Klimachev, Andrey A. Kotkov, P.N. Lebedev Physical Institute (Russian Federation)

A broadband IR hybrid laser system emitting within 2.5 – 16.5 micron is discussed. The system consists of two IR electric discharge molecular lasers emitting high-power nanosecond and/or microsecond pulses. Radiation of these lasers is mixed in various nonlinear crystals producing sum and difference frequency conversion into above mentioned IR spectral range.

9251-34, Session 11

Coherent combination as performance scaling concept of ultrafast lasers *(Invited Paper)*

Jens Limpert, Tino Eidam, Arno Klenke, Marco Kienel, Sven Breitkopf, Andreas Tünnermann, Friedrich-Schiller-Univ. Jena (Germany)

We present a system-architecture for high-repetition-rate Joule-class fiber lasers ideally suited for a number of demanding applications in science, medicine and industry. The necessary power levels are achieved by using temporally and spatially separated amplification and subsequent coherent combination.

9251-35, Session 11

Single-mode single-frequency high peak power all-fiber MOPA at 1550 nm *(Invited Paper)*

Leonid V. Kotov, Fiber Optics Research Ctr. (Russian Federation) and Moscow Institute of Physics and Technology (Russian Federation); Mikhail E. Likhachev, Mikhail M. Bubnov, Vladimir M. Paramonov, Fiber Optics Research Ctr. (Russian Federation); Mikhail I. Belovolov, A. M. Prokhorov General Physics Institute (Russian Federation); Denis S. Lipatov, Institute of Chemistry of High-Purity Substances of the Russian Academy of Sciences (Russian Federation) and Lobachevsky State Univ. of Nizhni Novgorod (Russian Federation); Aleksei N. Guryanov, Institute of Chemistry of High-Purity Substances of the Russian Academy of Sciences (Russian Federation)

High power nanosecond single-frequency Er-doped fiber laser sources near 1550 nm are of interest for many application such as remote sensing and LIDAR due to high atmosphere transparency, eye-safety and availability of telecom fiber components. The all-fiber configuration results in a high efficiency, reliability and compactness of such a systems. On the other hand it also strongly limits the output peak power due to stimulated Brillouin scattering (SBS). Up to date, SBS threshold of less than 500W was achieved with a standard commercially available large mode area Er-doped fibers. In this study we present a record peak power single frequency master oscillator power amplifier (MOPA) system based on a newly-developed large mode area Yb-free Er-doped fiber.

A fiber Bragg grating wavelength stabilized diode laser at 1551 nm with ~2 MHz spectral width was used as master oscillator in our work. Its radiation was externally modulated with a 5 kHz repetition rate and 92 ns pulse duration and then amplified in a core pumped Er-doped fiber amplifier up to an average power of 4 mW. The amplified spontaneous emission (ASE) generated at the last preamplifier stage was suppressed by a narrow-band (0.7 nm) DWDM filter. The last MOPA stage was based on the recently developed single-mode double-clad Yb-free Er-doped fiber with a mode field diameter of 25 microns and pump clad-absorption of 3 dB/m at 980 nm. The pump and the signal were launched into this fiber through a commercial pump combiner in a co-propagating amplifier scheme. Backward SBS

signal was monitored through a 10 dB coupler spliced to the input port of pump combiner.

At first, we used a 3 m long active fiber in the amplifier. In such configuration 800 W of peak power was achieved at the output of amplifier together with~ 12 % slope pump conversion efficiency. Further power scaling was limited by SBS. After that we shortened the fiber length to 1 m. As a result, owing to large unabsorbed pump power, the efficiency decreased to ~5 %. However, a peak power of more than 3.5 kW was obtained before the SBS threshold. In this case, the pulse shape changed and its duration decreased to ~60 ns owing to inversion depletion after propagation of the forward front of the pulse.

In conclusion we present results of narrow bandwidth nanosecond pulses amplification in a large mode area Yb-free Er-doped double clad fiber. To the best of our knowledge, the peak power of more than 3.5 kW reported here is the highest value ever published for a single-frequency single-mode silica-based fiber laser system operating near ?=1550 nm.

9251-36, Session 11

Q-switched fiber laser with topological insulator Bi2Se3 film

Jinrong Tian, Yanrong Song, Zhenhua Yu, Zhiyuan Dou, Kexuan Li, Beijing Univ. of Technology (China)

High-repetition rate Q-switched fiber lasers are particularly desirable in medicine, security, high-resolution photoacoustic microscopy, remote sensing and optical parametric oscillator. Passively Q-switching technique with saturable absorber was the most effective method to achieve the Q-switched operation in lasers. In the past two decades, there are several kinds of SAs, such as dye SAs, semiconductor saturable absorber mirrors [1], carbon nanotubes [2], and graphene [3]. In order to obtain ideal SAs with the characters of wavelength-independent, low saturable optical intensity, high damage threshold and large modulation depth, researchers are still making effort. Most recently, the topological insulator (TI) was studied and the character of the optical saturable absorption of this material was confirmed. Till now, the TI has been used as the SA for mode locking and Q-switching technology [4-7].

In this paper, we demonstrated a high-repetition rate Q-switched fiber laser with topological insulator Bi2Se3 absorber. The absorber was made into a film structure by spin-coating method using few-layer Bi2Se3 nano-platelets which had regular shape. The uniform film had a low saturable optical intensity of 11MW/cm2,which is the lowest saturable optical intensity in the saturable absorbers made by topological insulator till now. By inserting the absorber film into an Erbium-doped fiber laser, a high-repetition Q-switched laser with the repetition rates from 459 kHz to 940 kHz was achieved. The maximum output power was 22.35 mW with the shortest pulse duration of 1.9 ?s. Both of the repetition rate and the output power were higher among the Q-switched fiber lasers with topological insulator absorber.

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9251-37, Session 12

CFD DPAL modeling for various schemes of flow configurations *(Invited Paper)*

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An analysis of kinetic and fluid dynamic processes in diode pumped alkali lasers (DPALs), based on a two- and three-dimensional computational fluid dynamics (2D and 3D CFD) models, is reported. Three schemes for the DPAL gas dynamics are considered: static, subsonic and supersonic. In the static DPAL the heat transfer from the pump volume is mainly by free convection resulting in considerable heating of the pump volume and large temperature gradients in the gas medium. Effects of free convection and temperature diffusion in a static DPAL are studied. The supersonic DPAL eliminates the heating problem by forced convection. A supersonic device with Mach number 2.5, turbulent flow and optical axis perpendicular to the flow direction was modeled. The DPAL kinetic processes considered include excitation of alkali atoms to higher levels by photoexcitation and by energy pooling collisions and subsequent losses of alkali atoms due to ionization and chemical reactions. The coupled equations for laser kinetics, laser optics and gas flow were solved applying 2D and 3D CFD models. Using these CFD models, the flow pattern and spatial distributions of the pump and laser intensities in the resonator are calculated for Cs DPALs. The CFD models results for laser power are compared to experimental results of Cs DPALs.

9251-38, Session 12

Comparison of semi-analytical to CFD model calculations and to experimental results of subsonic flowing-gas and static DPALs

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Diode pumped alkali lasers (DPALs) are currently the most promising and extensively studied gas lasers due to their great potential as high power lasers [1]. They operate on the D1(n 2P1/2 ? n2S1/2) transition of the alkali atoms (where n = 4, 5, 6 for K, Rb and Cs, respectively), pumped via the D2(n2S1/2 ? n2P3/2) transition, followed by rapid relaxation of the upper to the lower fine-structure level, n2P3/2 to n2P1/2. At high pump power (> 50 W) the heat release due to relaxation between the fine-structure levels of the alkali atoms and quenching of these levels result in a considerable increase of the temperature T, whereas Photo- and Penning- ionization of the higher levels n2D3/2,5/2 and (n+2)2S1/2 levels (excited by pump and laser radiation and by energy pooling collisions) result in reduction of the density of neutral atoms participating in lasing. Both the temperature rise and the loss of atoms decrease the slope and the overall optical-to-optical efficiency of the DPALs. To avoid the temperature rise and replenish the lost alkali atoms, flowing-gas DPALs are used [2].

A semi-analytical model was applied to Cs DPALs and the results are in good agreement with measurements in a static [3] and 1-kW flowing-gas [2] DPALs [4-6]. Comparison of the semi-analytical to 2D CFD models applied to subsonic flowing-gas DPAL with narrow band pumping shows that for low pump power both models predict very close values of the

laser power; however, at higher pump power, corresponding to saturation of the absorption of the pump transition, the values of the laser power calculated using the 2D CFD model are much higher than those obtained using the semi-analytical model. The results of work in progress applying both semi-analytical and 2D CFD models to the 1-kW flowing-gas DPAL with broad band pumping [2] will be reported.

Studies of fluid dynamics effects in static DPALs showed that the main assumption of the semi-analytical model on uniform densities of different species and of the temperature is poor approximation. Work in progress on the application of 3D CFD model to the static DPAL, taking into account natural convection, will be reported and compared with the semi-analytical model and with experimental measurements [3].

The models were applied also to both static and flowing gas subsonic K DPAL, where the effects of the multi-transversal mode lasing were taken into account and optimal conditions corresponding to the maximum optical-to-optical efficiency were found.

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9251-39, Session 12

Theoretical studies of the feasibility of supersonic DPALs

Salman Rosenwaks, Boris D. Barmashenko, Karol Waichman, Ben-Gurion Univ. of the Negev (Israel)

Results of recent semi-analytical and three dimensional computational fluid dynamics (3D CFD) modeling of supersonic diode pumped alkali lasers (DPALs), as well as summary of work in progress, will be reported. DPALs have been extensively studied in the past few years [1,2]. Static and flowing-gas DPALs have been investigated. Modeling of these devices has been conducted as well [1,3-8] and fluid dynamics and kinetic processes have been taken into account, but until recently only flowing-gas DPALs with subsonic velocity of the gas was considered. Following our recent work on supersonic DPALs [9,10], we further explore in the present study the feasibility of operating DPALs with supersonic expansion of the gaseous laser mixture, consisting of alkali atoms, He atoms and (frequently) hydrocarbon molecules. The motivation for this exploration stems from the possibility of fast and efficient cooling of the mixture by the supersonic expansion. In our recent study [9] we have reported on semi-analytical modeling for a supersonic Cs DPAL with parameters similar to those of the 1-kW flowing-gas subsonic Cs DPAL [4], the maximum power, Plase, for the former is larger than that for the latter by 25%. Optimization of He/CH4 buffer gas composition and flow parameters shows that for the resonator parameters of Ref. 4, extremely high lasing power and optical-to-optical efficiency, 21 kW and 82%, respectively, is achievable in the supersonic device. For the supersonic K DPAL, Plase = 43 kW, is 70% larger than for subsonic with the same resonator and K density at the inlet, the maximum optical-to-optical efficiency being 82%. Preliminary results of 3D CFD modeling of supersonic DPALs have been reported in [10] and further modeling which is currently in progress will be reported in detail and the anticipated advantages and possible difficulties in this type of DPALs will be critically reviewed.

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9251-40, Session 12

New concepts of realizing chemical oxygen lasers

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New concepts are presented to realize a chemical oxygen laser (COL) oscillating from O2(1?) to O2 (3?). The chemical oxygen iodine laser (COIL) utilizes the energy transfer from chemically generated excited oxygen O2 (O2(1?)) to iodine I (2P3/2) because the stimulated emission cross section of O2 (O2(1?)) is very small. But extractable laser energy has no relation with its stimulated emission cross section, therefore a COL has a potential to give high output pulsed energy if it has a long laser cavity which can give positive gain. Moreover considering the triplet ground level (O2 (3?)) , achieving the inversion population (= O2 (1?) - 1/3?O2 (3?)) is not difficult. Since the previous report elucidated the problems 1), the proposed concepts provide solvable ideas to achieve oscillation. Additionally rate-equation based simulation indicates that as short as <1 ms of pulsed output can be expected by a Q-switch operation, which can give ~1000 times higher peak power than an equivalent-level cw COIL.

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9251-41, Session 12

DPAL research in Changsha

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Alkali laser had been one of the most promising routes to high energy laser during the past decade. As the first group realized DPAL and XPAL lasing in China, we had conducted extensive theoretical and experimental efforts to further clarify the mechanism of alkali lasers, such as exploring scaling parameters design balance and MOPA configuration amplified spontaneous emission suppression in DPAL based on our self-developed fast converging algorithm, XPAL’s continuous wave operation threshold, performance degradation of VBG narrowed diode laser array and stacks due to conductive thermal flow, heat deposition induced gas dynamic parameters variation estimation, local atomic number density change measurement with single frequency tuning laser, ionization and other higher level nonlinear effects with opto-galvanometer method. Based on above research works, the preliminary considerations and conclusions for alkali laser scaling were given.

9251-43, Session 12

Study of potassium DPAL operation in pulsed and CW mode

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No Abstract Available

9251-42, Session PS

Middle spatial frequency measurement in high-power laser system

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Power spectral density (PSD) is being used to evaluating the surface finish and transmitted wavefront in mid-spatial frequency for optics in high power laser system, but PSD character curve only shows the unqualified frequency range and cannot find the corresponding region of this frequency range to guide the further processing. In order to solve this problem, we used two-dimensional continuous wavelet transform to process the unqualified frequency range and obtained the certain scatter diagram in spatial domain. We compared the effects on results which were processed by two different wavelet transformations. We also compared the analyzing results by using wavelet and Fourier transform. The experiments show the use of wavelet can find the corresponding region of certain frequency range effectively and improve the finish of optics.

9252-1, Session 1

Millimeter wave radar system on a rotating platform for combined search and track functionality with SAR imaging *(Invited Paper)*

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Ground based millimeter wave radar sensors offer the potential for a weather-independent automatic ground surveillance at day and night, e.g. for camp protection applications. The basic principle and the experimental verification of a system concept is described, which by means of an extreme off-axis positioning of the antenna(s) combines azimuthal mechanical beam steering with the formation of a circular-arc shaped synthetic aperture (SA).

In automatic ground surveillance the function of search and detection of moving ground targets is performed by means of the conventional mechanical scan mode. By designing the rotated antenna structure as a small array with two or more RX antenna elements with simultaneous receiver chains instantaneous tracking of multiple moving targets is possible (monopulse principle). The simultaneously operated SAR mode yields areal images of the distribution of stationary scatterers. For ground surveillance application this mode is best suited for identifying possible threats by means of change detection.

The feasibility of this concept was tested by means of an experimental system comprising a 94 GHz (W band) FM-CW module with 1 GHz bandwidth and two RX antennas with parallel receiver channels, placed off-axis at a rotating platform. SAR-mode and search/track mode were tested during an outdoor measurement campaign. The scenery of two persons walking along a route via a road and partially through forest served as test for the capability to track multiple moving targets. For SAR mode verification an image of the area composed of roads, grassland, woodland and several man-made objects was reconstructed from the measured data.

9252-2, Session 1

Ultrawide band microwave 3D imaging footwear scanner

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The heightened threat at airports of concealed weapons, explosives and contraband in footwear has led to investigation and development of new devices that can be deployed for security screening to facilitate the checking process. After the shoe bomber in 2001, each passenger has to divest their shoes to be x-rayed with luggage at checkpoints before boarding the plane and this has caused inconvenience to passengers and has reduced throughput at airports. Many devices were developed such as metal detectors, x-ray, microwave and millimetre wave imaging to allow for screening at airports and venues. Currently, the metal detectors are employed to detect concealed metallic objects in shoes, but cannot locate non-metallic objects or material such as ceramic guns or knives, plastic guns and explosives. To address these deficiencies, Ultra Wide band (UWB) footwear scanners swept between 15 to 40 GHz have been designed and built, which evaluate shoes whilst they are still worn and have demonstrated the ability to detect concealed metallic and dielectric objects. To detect threats concealed in shoes, a method of screening has been developed where the passenger stands in a prescribed platform while the scanning is performed on the shoes. By moving a transceiver horn antenna along the heel and sole of the shoe, 2D data is obtained from the different positions along the shoe and processed using techniques of data processing to enhance and localise the concealed threat; a 2D image corresponding to a cross section through the shoe is built up. An improved 3D UWB footwear scanner prototype has been developed based on an x y stage, where a 3D image or 2D cross sections of the microwave image of the different parts along the shoe are acquired by moving the transceiver horn antenna beneath the shoe platform. The scan obtained from each position along the shoe is composed of reflected signals from the various interfaces, air, platform, shoe, concealed material and horn. To enhance the required signal, background subtraction, gating, windowing, deconvolution with a reference signal and Inverse Fast Fourier Transform (IFFT) are applied to the scans. The image of the deconvolved data shows better separation of the layers in the depth direction of the shoe. To further focus the image in both depth and length of the shoe, a Synthetic Aperture Radar (SAR) technique is applied to the processed data. To improve the lateral and range resolutions a higher frequency and large sweep bandwidth are essential for separating the scattering from the layers of the shoe and concealed material. The K and Q bands between 15 to 40 GHz, show good transmission through the heel and sole of the shoe and lateral and range resolutions. Results are presented for footwear, some modified by the inclusion of concealed material, procedures of enhancing the image employing filtering and SAR techniques are compared with Finite Element Modelling (FEM) simulations.

9252-3, Session 1

Simulation and experimentation in three dimensional near-field aperture synthesis imaging

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Simulation and experimentation of three dimensional passive near-field imaging is presented. The three-dimensional spatial resolving capabilities of an aperture synthesis imager are examined by evaluating the spatial variation in the phase of the cross-correlations in the near-field array antenna regions. Considerations are made as to how best to exploit this capability, which appear somewhat like a new field of tomographic microscopy. Experimental data from a 22 GHz aperture synthesis imager are used to support this three dimensional imaging capability. Of particular interest is what determines the fundamental limit of the spatial resolution in this regime, as the sensor is quite different to other classical imaging techniques in the acoustic, radar, optics and x-ray bands. Simulations and measurements to date suggest a sub-wavelength resolving capability may be possible. The paper further examines a near-field numerical simulation of the van Cittert Zernike theorem in the regime between antenna inductive regime and the Rayleigh range. For these near-field regimes where spherical geometry is required, fundamental linearly polarised radiators become resolved into orthogonal detection modes. For the Fresnel region of the van Cittert Zernike theorem this was only a small perturbation, but as one moves closer to the antenna inductive region, relevant for security screening, polarimetric sensing becomes important. A model for this near-field region is presented and considerations given as to how this might be verified experimentally using the existing 22 GHz aperture synthesis imaging system. The application of this sensor is primarily security screening of personnel. However, moving into the near-field with a sub-wavelength resolving capability will stimulate interests in a range of new applications, such as three-dimensional medical thermography.

9252-4, Session 1

Millimeter waves sensors based very inexpensive plasma LED lamps comprehensive video rate real time imaging in three-dimensional space

Assaf Levanon, Yitzhak Yitzhaky, Natan S. Kopeika, Daniel Rozban, Ben-Gurion Univ. of the Negev (Israel); Amir Abramovich, Ariel Univ. (Israel)

In recent years, much effort has been invested to develop inexpensive but sensitive Millimeter Wave (MMW) detectors that can be used in focal plane arrays (FPAs), in order to implement real time MMW imaging. Real time MMW imaging systems are required for many varied applications in many fields as homeland security, medicine, communications, military products and space technology. It is mainly because this radiation has high penetration and good navigability through dust storm, fog, heavy rain, dielectric materials, biological tissue, and diverse materials. Moreover, the atmospheric attenuation in this range of the spectrum is relatively low and the scattering is also low compared to NIR and VIS. The lack of inexpensive room temperature imaging systems makes it difficult to provide a suitable MMW system for many of the above applications. In last few years we advanced in research and development of sensors using very inexpensive (30-50 cents) Glow Discharge Detector (GDD) plasma indicator lamps as MMW detectors. This paper presents three kinds of GDD sensor based lamp Focal Plane Arrays (FPA). Those three kinds of cameras are different in the number of detectors, scanning operation, and detection method. The 1st and 2nd generations are 8?8 pixel array and an 18?2 mono-rail scanner array respectively, both of them for direct detection and limited to fixed imaging. The last designed sensor is a multiplexing frame rate of 16x16 GDD FPA. It permits real time video rate imaging of 30 frames/sec and comprehensive 3D MMW imaging. The principle of detection in this sensor is a frequency modulated continuous wave (FMCW) system while each of the 16 GDD pixel lines is sampled simultaneously. In this case 32 ms are required to acquire a frame, and power consumption is about 16 Watts. Direct detection is also possible and can be done with a friendly user interface. This FPA sensor is built over 256 commercial GDD lamps with 3 mm diameter International Light, Inc., Peabody, MA model 527 Ne indicator lamps as pixel detectors. All three sensors are fully supported by software Graphical Unit Interface (GUI). They were tested and characterized through different kinds of optical systems for imaging applications, super resolution, and calibration methods. The last generation and the most advanced 16x16 sensor is able to employ a chirp radar method to produced depth and reflectance information in the image. This enables 3-D MMW imaging in real time with video frame rate. The radar system requires that the millimeter wave detectors (GDD) operate as heterodyne detectors, giving for each pixel the depth information according to value of difference frequency, in addition to the usual reflectance 2 dimensional image. In this work we demonstrate different kinds of optical imaging systems. Those systems have capability of 3-D imaging for short range and longer distances to at least 10-20 meters.

9252-5, Session 1

Multistatic short range imaging with multipath signals *(Invited Paper)*

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The screening of persons at the airport, check points or other security relevant public or military areas has become more important. The required technologies have to be very efficient and have to offer a high level of security at the same time. Thus the scanners should have a high image quality with respect to spatial resolution, dynamic range and illumination of the person. Most familiar techniques for close-range imaging in the millimeter wave region are passive and active ones. The first one is a non-radiating concept which detects the emitted thermal radiation of a person and the concealed objects as well as the reflected signals from the thermal background radiation. This diffuse illumination and self-radiation of the measurement object leads to an inherent well-illuminated imaging result. This means passive images do not suffer from shaded regions or bad illuminated areas. Furthermore these systems offer a good contrast in outdoor applications due to a low background radiation from the sky but suffer from a low contrast in indoor applications due to a high background radiation from surroundings. No range information is available with passive imagers as well, since the received signals are equivalent to thermal noise. Active systems illuminate the person with electromagnetic waves and the scattered fields are detected coherently or incoherently. This leads to images with high dynamic range for indoor and outdoor applications. Furthermore, localization in range is possible if a broadband transmit and receive signal is applied. The utilization of mm-waves are interesting because of an inherent high resolution and the capability to penetrate clothes but not the human skin.

This paper deals with a full electronic active mm-wave scanner without any moving mechanical parts and which is capable to scan a living person in the frequency range from 70 to 80 GHz in less than 20 ms. This scanner consist of 3008 transmit and 3008 receive antennas which are distributed over an aperture of 1 m x 2 m. The multistatic antenna arrangement offers high measurement speed due to parallelization on receive and the opportunity of a greatly sparse antenna arrangement to reduce the hardware effort. Optimum spatial resolution of the 3D image is guaranteed by digitally focusing the received data by means of digital beam forming.

Drawbacks of an active illumination are shading effects or bad illuminated areas due to specular reflections depending on the respective transmitter and receiver positions. Especially in personnel screening the human skin behaves as a smooth mirror for millimeter waves. For instance this leads to a poor illumination of the lower legs and ankles since the lowest antenna position is limited by the floor and the scanner mechanics. This drawback can be circumvented by constructively applying, normally unwanted, multipath signals to enhance the object illumination. We present an approach which incorporates the multipath signals resulting from floor reflections to enhance the illumination of the lower legs. The proposed approach can be applied to enhance the illumination of other body regions as well.

9252-6, Session 1

Design and first-season operation of ACTPol, a millimeter wavelength, polarization sensitive receiver for the Atacama Cosmology Telescope

Benjamin L. Schmitt, Univ. of Pennsylvania (United States); ACTPol Collaboration, Princeton Univ. (United States)

We highlight considerations for the design and operation of ACTPol, a new receiver for the Atacama Cosmology Telescope (ACT), capable of making polarization-sensitive, millimeter-wavelength observations of the Cosmic Microwave Background (CMB) at arcminute angular scales. ACT is a six-meter telescope located in northern Chile, dedicated to enhancing our understanding of the structure and evolution of the early Universe by direct measurement of the CMB. We describe the design of the ACTPol focal plane at full-deployment, consisting of dual 150 GHz array package modules and a multichroic array package with simultaneous 90 GHz and 150 GHz sensitivity. Each of these detector array packages resides behind a set of custom-designed, high-purity silicon reimaging optics with a novel anti-reflective coating geometry, the characteristics of which will be detailed. Each array package module consists of ~1000 transition-edge sensor (TES) bolometers used to measure the response of ~500 feedhorn-coupled polarimeters, enabling characterization of the linear orthogonal polarization of incident CMB radiation. The polarimeters are arranged in

three hexagonal and three semi-hexagonal silicon wafer stacks, mechanically coupled to an octakaidecagonal, monolithic corrugated silicon feedhorn array (~140 mm diameter). Readout of the TES polarimeters is achieved using time-division SQUID multiplexing. Each array package is cooled using a custom-designed dilution refrigerator providing a 100 mK bath temperature to the detectors, which have a target Tc of 150 mK. Given the unique cryomechanical constraints associated with this large-scale monolithic superconducting focal plane, we address the design considerations necessary for integration with the optical and cryogenic elements of the ACTPol receiver. With first-season operations completed in January 2014, details of the ACTPol receiver deployment and early results will be highlighted. Finally, specific consideration will be given to the context of these associated technologies and their synergistic application supporting allied field applications, including interests in national security, counterterrorism, and nuclear nonproliferation.

9252-7, Session 1

A circular-shaped time-delay line inspired by CRLH TL unit cell for UWB operation

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This paper presents the design of a circular-shaped ultra-wideband (UWB) time-delay lines inspired by the use of composite right/left-handed transmission line (CRLH TL) unit cells. A rotated version of a conventional CRLH TL unit cell is used as the basic element to achieve UWB operation. For comparison, time-delay lines using the right-handed transmission line (RH TL) and CRLH TL unit cells are also studied, fabricated and measured. Simulation and measurement results show that our proposed time-delay lines have high return loss, low insertion loss, UWB operation and much longer time delays than that of the time-delay line based on RH TL.

9252-8, Session 2

Characterization of Plasma Treated Surfaces for Food Safety by Terahertz Spectroscopy *(Invited Paper)*

Katerina Sulovska, Marian Lehocky, Tomas Bata Univ. of Zlin (Czech Republic)

This contribution deals with the characterization of modified LDPE surfaces with antibacterial properties via Terahertz spectroscopy. Three monomers were used for grafting onto air radiofrequency plasma activated LDPE surface, which created a brush-like structure. Next, the antibacterial agents were anchored to the surface. Such created antibacterial surfaces were tested for antibacterial activity for two bacterial strains - E. coli and S. aureus. Materials were further tested for the presence of antibacterial agent molecules, in our case by means of terahertz spectroscopy. Each material was tested on two spectroscopes - the SPECTRA and the OSCAT terahertz instruments. In contrast to same tests by ATR-FTIR spectroscopy, some peaks and changes after whole process are more visible. On the other hand, changes on surface after covering samples by antibacterial agents were less visible. Depending on the monomers used, the material embodied higher or lower antibacterial activity.

9252-9, Session 2

Distinguishing of different kinds of gunpowder using various methods based on Terahertz radiation

Tomás Gavenda, Vojtech Kresalek, Tomas Bata Univ. of Zlin (Czech Republic)

The research performed by authors of this article in the year 2013 [1] lead to the following presented research. Different samples of commercially known kinds of gunpowder prepared by various manufactures were measured to obtain presented data. The article published in 2013 [1] proved, that particular samples can be distinguished from each other using terahertz time-domain spectroscopy. This article presents results of measuring and analysing of gunpowder samples using other methods based on terahertz radiation.

Ten different samples of gunpowder were measured during the research. Most of them were based on nitrocellulose, but components of each sample differ. Systems TPS Spectra 3000 by TeraView Ltd. and Tera OSCAT by Menlo GmbH. were used for measurements. Several terahertz radiation based methods were used for researching the possibility of distinguishing different kinds of gunpowder, such as terahertz imaging (using both transitive and reflective imaging method), ATR spectroscopy and reflective variant of time-domain spectroscopy. Frequency ranges differ in dependence on used method, but the range from 0.5 THz to 2.0 THz was measured mostly. Presented research also contains results of measurements of gunpowder compounds, for example compounds with polymer materials (like polyethylene). These measurements are important because of the need for development of new possibilities to detect and identify dangerous materials at airports or other public places.

Most of preliminary results is presented by images and graphs. The terahertz spectrum images are obtained via reflective or transmitive imaging technique. The comparison of reflected (or transmitted) terahertz signals is presented. It is possible to calculate the frequency spectrum, absorbance and other properties of gunpowder, which are different then properties of the paper base layer. The paper base layer is relatively inert to terahertz radiation. Colour pallet of the image symbolises the absorbance of measured material. Blue areas represent points with high absorbance and red areas represent points with low absorbance.

Main contribution of this research is extension of knowledge in the domain of detection, identification and distinguishing of different kinds of gunpowder, which are commercially available and therefore exploitable as dangerous explosive materials. This article, together with the previous presented and already published article [1], makes comprehensive result of gunpowder properties measurement using methods based on terahertz radiation.

[1] Gavenda T., Kresalek V., “Terahertz time-domain spectroscopy for distinguishing different kinds of gunpowder,” Proc. SPIE 8900, 6 pages (2013).

9252-10, Session 2

The development of a fully polarimetric radar for the detection of concealed weapons

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Radar is becoming an increasingly popular tool in the screening of personnel for concealed threat items. The development of fully polarimetric radars for this purpose seems to be lacking the attention that dual-polar, direct-detection radars are currently receiving. This paper illustrates the benefits of developing a fully polarimetric radar by introducing a roll-invariant detection algorithm. This is only possible with

full polarization, amplitude and phase measurements. This algorithm is based on an eigenvalue decomposition of a target's coherency matrix, which is a proven technique in the field of Earth Observation.

This paper discusses the theoretical foundations of the above algorithm and the initial analysis of threat detection is performed using simulated data. Discussion of the set-up of the simulation in a commercial electromagnetic solver is presented and all assumptions used are explained and justified.

The analysis will then be expanded to consider experimental data and the measurement procedure used in the collection of data will be covered in detail. The discussion focuses on de-embedding of the S-parameters through calibration followed by technical details of antenna mismatch suppression. Also covered will be a selection of radar parameters chosen carefully to avoid aliasing in the sampled signals.

This paper concludes with a summarized presentation of a novel technique of detecting concealed threat items using fully polarimetric radar.

9252-12, Session 2

Waveform diversity in mmw and terahertz sensing applications

Douglas T. Petkie, Ivan R. Medvedev, Wright State Univ. (United States)

Sensing applications in millimeter, submillimeter-wave, and THz spectral regions of the electromagnetic spectrum continue to develop at a rapid pace with the advancement of technology over the past several decades. While many of these applications share the same base technology, the phenomenology can vary drastically in the 100-1000 GHz range. This paper will highlight some of the basic physics that must be considered to optimize a particular sensing application and how waveform diversity (carrier frequency, modulation, polarization, amplitude) and other system attributes play a critical role in the sensing strategy. Several non-destructive sensing applications will be discussed that use a broad range of spectroscopic, radar, and imaging techniques, each based on a similar continuous-wave sensing platform. In particular, we will focus on recent spectroscopy applications that included breath analysis using traditional absorption spectroscopy as well as the development of a MEMS-based photoacoustic spectrometer that greatly reduces the spectrometer footprint. Recent radar work focuses on FMCW or chirp techniques to range resolve different objects so as to monitor the micro-Doppler signatures of each. Results from non-destructive imaging as a function of frequency and polarization will also be presented. These are all done with very similar systems that employ frequency multiplication of highly coherent continuous-wave sources.

9252-13, Session 3

Josephson junction as the receiving and measuring element in panoramic receiver: frequency meter in Terahertz band *(Invited Paper)*

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Josephson junction (JJ) can be used as the criterion in single-block super wide band frequencymeter and as the sensitive element in the super wide band panoramic receiver. There presented the theoretical and experimental investigations and described the innovation decision about to combine both devices in one new microwave device. JJ in this case works in self-pump mode regime. New device can be especially convenient for the experimental purposes with new generation structures when radiated power is small and frequency are unknown correctly.

9252-14, Session 3

Design of switched-line phase shifters with constant phase shift using CRLH TL

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900 and 1800-switched-line phase shifters using composite right/left handed transmission line (CRLH TL) are presented. To achieve a relatively constant phase shift over a large bandwidth, CRLH TLs implemented using lumped elements and right-handed transmission lines (RH TLs) are used as the reference and delay arms, respectively, of the phase shifters. Computer simulation is used to study and design the phase shifters. The phase shifters are also fabricated and measured to verify the simulation results. For comparison, traditional 900 and 1800-switched-line phase shifters are also designed and simulated. Simulation and measurement results show that, the proposed phase shifters have a constant phase shift, a high return loss and a low insertion loss across the operating frequency band.

9252-15, Session 3

Silicon optics for focusing of Novosibirsk free electron laser radiation in a given two-dimensional domain

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Diffractive optical elements (DOEs) are beneficial for beam manipulation at THz frequencies. Such applications as imaging, material ablation, generation of continuous optical discharge, and even those more exotic for application in the terahertz range, namely field ionization of individual atoms, require focusing of THz radiation, often in a given two-dimensional domain. Binary silicon-based diffractive optical element (DOE) - Gaussian-to-Square focuser (diameter of aperture is 30 mm) for the terahertz spectral range has been designed and characterized using terahertz radiation of the Novosibirsk Free Electron Laser (NovoFEL) at the wavelength of 141 mm. The preliminary experiments have demonstrated feasibility of application of binary silicon DOE for focusing of terahertz radiation into pre-given focal domain. The genetical algorithm has been used for DOE design. The binary microrelief has been realized by use ion-chemical etching. For a larger diffraction efficiency, the element was covered with a Parilene ? layer. The radiation resistance of the Parilene C layer was examined by focusing radiation on the layer. The layer was not damaged

under exposure to radiation of an average power of up to 4 kW/cm2. The results of simulation are in good agreement with experiment.

9252-16, Session 3

Binary DOE with enhanced focal depth to focus terahertz Novosibirsk free electron laser radiation

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Diffractive optical elements (DOEs) are most beneficial for beam manipulation at THz frequencies. Binary silicon diffractive optical elements (diffractive lenses and beam-splitters) for manipulation by terahertz Novosibirsk Free Electron Laser (NovoFEL) radiation have been considered in before. Such applications like imaging, material ablation, generation of continuous optical discharge, and even more exotic for the terahertz range application, namely the field ionization of individual atoms, require focusing of THz radiation, often with a enhanced focal depth.

The diffractive micro-optical elements, which shape the given longitudinal distributions of intensity (elongated axial light segment, sets of sequential axial focuses and etc.) are used in many fields of laser technology for visible and infrared ranges of optical spectrum. For example, in aligning and juxtaposition of units at great distances, in forming of image of extended or moving objects, that is especially actual in medicine, and for a nondestructive search of materials and devices, in metrology for scanning and interference optical systems. The use of binary DOEs forming given longitudinal distributions for interferometry is also presented in before. The fast development of terahertz laser technology needs the opportunity for focusing of terahertz laser radiation with enhanced focal depth. In this paper we report characteristics of binary silicon DOE focusing onto an axial segment for the terahertz spectral range.

9252-17, Session 3

Broadband and polarization-insensitive Terahertz absorber

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A simple broadband terahertz absorber fabricated by etching two-dimensional periodical gratings on a 0.5??cm p-type silicon wafer is designed, measured and analyzed. The absorber is experimentally demonstrated that it can reach an over 95% absorption in the frequency range of 1~2 THz with incident angle ranging from 0° to 60°. The combination of the destructive interference in the lower frequency and the diffraction in the higher frequency causes the two absorption peaks which are interwoven with each other, leading to the broadband characterization of the absorber. Such terahertz absorbers are also insensitive to the polarization of the incident wave due to the symmetric structure. This kind of broadband omnidirectional wide angle perfect absorber will have potential applications such as micro bolometers, anti-radar cloaking and so on.

9252-23, Session PS

A method of 3D reconstruction via ISAR sequences based on scattering centers association for space rigid object

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PURPOSE

Inverse Synthetic Aperture Radar (ISAR) image relies on target motion to provide cross-range resolution and is derived as a temporal sequence. As it moves, the target presents different aspects, which can be integrated to derive the third dimension?so it provides an opportunity for 3D reconstruction. With the improvement of the imaging resolution, reconstruction of 3-D stereo objects via ISAR image becomes more attractive. As the research in computer vision shows, just a few points (five for perspective) in two views are theoretically sufficient to yield the position of those points in three-space, however, small errors in point locations and association can lead to large differences in the derived 3D positions.

Different from the optical images, ISAR image is consisted of many sparse scatters, usually vary with different view angles and suffer jamming and shelter, which make the feature point location and association difficulty.

The main purpose of this paper is to improve the accuracy of scattering centers association, and then enhance the precision of three-dimensional reconstruction.

METHODS

The algorithm can be summarized as follows:

1) Scatter centers extract and association;

2) Three-Dimensional reconstruction and the association result optimize;

3) Repeat step2 until satisfactory reconstructed result are obtained.

Firstly, most space object is approximate to cooperative target, because it has a specific orbit. This paper analyzes the effects , which the orbit motion makes for scattering centers trajectory, and introduce this constraint to scattering center association improve the performance .In addition to, Kalman filter and a method of data association are used for scattering centers association of ISAR sequences.

Secondly, we use the sequential factorization method to recovering 3D features from ISAR sequences, and then use a screening method based on clustering analysis to analysis the false points of reconstructed result, optimize or remove the wrong association which lead these false points.

Finally, repeat step 2 until satisfactory reconstructed result are obtained.

RESULTS

The simulation data show the validity of the algorithm. For simulation data, analysis and comparison is made between the model and reconstructed result. The result shows that the reconstructed size of the target is basically consistent with the actual size, and the precision of reconstructed result have a further improvement.

CONCLUSIONS

In this paper the effects of orbits motion makes for scattering centers trajectory is analyzed, and introduced to scattering centers association, as a constraint. A screening method of feature points based on clustering analysis is presented to analysis the false points of reconstructed result, and the wrong association which lead these false points. The loop iteration between 3D reconstruction and association result makes the precision of final reconstructed result have a further improvement. The simulation data shows the validity of the algorithm.

9252-24, Session PS

IF digitization receiver of wideband digital array radar test-bed

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1. PURPOSE

With the advantages of large instantaneous dynamic range, multiple simultaneous beam-forming, flexible controlling and adaptive null forming, Digital array radar (DAR) has been developed a lot in recent years. However, due to the restriction of analog-to-digital converter (ADC) and limitation of data transferring rate, most of current DAR systems use stretch processing, which introduces extra analog components and results in deterioration of amplitude and phase distortion of the system. This paper demonstrates an advanced and flexible receiver capable of mounting directly to the antenna of wideband DAR. The main purpose is to realize IF direct digitization of analog signal and high speed serial data transferring. Moreover, key technologies in DAR such as channel calibration and wideband DOA are to be verified using measured data acquired by the system.

2. METHODS

The main contents in the paper can be summarized as follows:

1) Design and signal processing of the DAR receiving system;

2) Realization of RF direct digitization and high-speed data transferring;

3) Channel calibration and wideband DOA algorithm based on measured data.

In the first section, a flexible digitization DAR receiving system is demonstrated. The system contains 8 antenna elements which receives echoes with carrier frequency of 10GHz. A couple is mounted before down-converter to inject the calibration signal if needed. IF signal ranging from 0.6GHz to 3.0GHz is connected to the front-end. The front-end integrates two-stage low noise amplifier with a total gain of 60dB, followed by four band-pass filters of 500MHz bandwidth. With different center frequency, the filters divide the operating frequency into four frequency bands of 0.65-1.15GHz, 1.25-1.75GHz, 1.85-2.35GHz and 2.45-2.95GHz. Each receiver has a four-channel ADC, which can directly digitalize analog signals of one specialized frequency band from four RF front-ends. DDC and channel calibration are done by a Virtex-6 FPGA integrated on the receiver. Data are transmitted through fiber links to back-end processors, which carries out DBF, DOA, target tracking and other signal processing.

In the second section, the design of RF digitization receiver which is critical in DAR is described in detail, and the test results are illustrated as well. The receiver consists of a 10bits, four-channel ADC, a high-performance FPGA, four DDR3 chips and four optical transceivers. As is decried above, the operating frequency range is divided into four bands, which are connected to the receiver through a switch. With the sampling rate of 1.2GHz, each channel of the ADC is capable of directly sampling the input signals of one frequency band (500MHz). These samples are then buffered into FPGA. In addition to serving as a FIFO, FPGA also carries out DDC and channel calibration. DDR3, with the depth of 256Mb and the width of 64bits in total, is used for storage of element-level data that can be streamed out for off-line processing. Finally, data is converted to bit stream and transported into the four optical transceivers, each of which supports 4*6.25Gbps of full duplex communication capability. Initial performance testing of the receiver has been conducted.

In the third section, an experiment is presented, aiming to demonstrate the functionality of DAR receiving system. In the experiment, an antenna is applied to transmit waveforms (500MHz wide, 2.7GHz center frequency, 20us LFM, 10GHz carrier frequency), and the calibration waveform is injected by the couple. The output data is stored in back-end processors for off-line analysis. The frequency response characteristic of each receiving channel is measured. Two channel calibration algorithms, frequency domain algorithm and improved Fourier Transform algorithm, are researched. The compare of them is presented, with the purpose of selecting one method that can achieve good performance as well as be suitable to be realized in FPGA. What's more, a sub-band joint DOA algorithm which is very effective on the background of strong interference is studied and verified by measured data.

3. RESULTS &CONCLUSIONS

In this paper, the receiver of an X-band, 8-element DAR test-bed that utilizes the IF direct digitization technology has been constructed. The main testing results of the receiver are illustrated as follows: ENOB 6.3bits, SRDR 45dB, transmitting rate up to 16*6.25Gbps. Two channel calibration algorithms are examined in an experiment. After calibration ,the amplitude distortion is below 0.5dB and phase distortion is below 3°. A sub-band joint DOA algorithm is used to process measured data, and the results show that DOA precession can reach 1°.

9252-25, Session PS

MTRC compensation in high-resolution ISAR imaging via improved polar format algorithm

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Inverse synthetic aperture radar (ISAR) can generate 2D image for a non-cooperative moving target for the purpose of military and civilian missions. High range resolution is proportional to the bandwidth of transmitted signal. High cross-range resolution is obtained by using a synthetic antenna aperture generated by the rotational motion of the target. With the increased 2-D resolution of the ISAR imaging, migration through resolution cells (MTRC) will be inevitably produced due to the rotational motion of the target, which may result in image defocusing both in the range and cross-range domain. This paper investigates the compensation of the MTRC in high-resolution ISAR imaging. An improved polar format algorithm (PFA) method based on minimum entropy criterion is proposed.

The PFA was used to compensate the MTRC in SAR imaging . Then it was introduced in ISAR imaging. The PFA interpolates the observed signal from polar sector support region to the Cartesian rectangular region. The fast Fourier transform (FFT) is applied to the signal to obtain the ISAR image. The PFA requires accurate rotation parameters to interpolate the complex data. However, it is difficultly to obtain them in practical applications. Let us consider a situation that a rigid-body target stably flies, the rotation angle of that target in coherent processing interval (CPI) is close to the rotation of radar line of sight (RLOS) . Therefore , an initial value of rotation angle can be estimated from the RLOS. Meanwhile, the rotation center is restricted to the target region of high range resolution profile (HRRP). With the estimated of initial rotation angel and center, the PFA is applied on the echo data iteratively to search the optimization solution based on minimum entropy criterion. The accurate rotation angle and center are obtained when the entropy of the ISAR image is minimized. Finally, the MTRC of the ISAR image is compensated by using the optimized parameters and the ISAR image can be best focused. Note that, to reduce the computational load of the proposed method, the golden section search method is used in the iteratively processing.

The procedure of the proposed algorithm is summarized as follows.:

Step 1: Take translational motion compensation to the echo data. The compensation constitutes of two steps: range bin alignment and phase compensation.

Step 2: Obtain the initial value of the rotation angle and center. The initial value of rotation angle can be calculated from the change of RLOS. The initial rotation center is set to y0=(y1+y2)/2, where [y1,y2] is the target region in HRRP.

Step 3: Apply the PFA iteratively to the echo data after translational motion compensation. The procedure starts with

the estimated initial rotation angle and center, and terminated when the entropy of the compensated ISAR image is minimized. In order to reduce the computational load, the 2-D iterative search is divided into two 1-D search. One is carried along the rotation angle and the other one is carried along rotation center. Each of the 1-D search is realized by using of the golden section search method. The accurate rotation angle and center can be obtained when the iterative search terminates.

Step 4: Apply the PFA to compensate the MTRC by the use of the obtained optimized rotation angle and center. After MTRC compensation, the ISAR image can be best focused.

Simulation data and real data confirm the effectiveness of the algorithm. The experiment was first carried on the simulated aircraft (MIG-25) ISAR data. After MTRC compensation, a well focused ISAR image was obtained. The cross range scaling (CRS) of the simulated image shows the accuracy of rotation parameters. The proposed algorithm was then carried on the real data provided by Science and Technology on Automatic Target Recognition (ATR) Laboratory of China was used. The data were collected from an ground based imaging radar. The target is a flying Boeing737. The compensated and CRS results indicate effectiveness on the real data.

Since MTRC is produced because of the rotational motion of the target in high-resolution ISAR imaging, a MTRC Compensation method in high-resolution ISAR imaging by using the improved PFA is proposed in this paper. The rotation angle and center are precondition for the MTRC compensation in ISAR imaging based on PFA. For a flying stably rigid-body target, the initial rotation angle and center can be obtained from RLOS and HRRP. With the estimated of the initial rotation angel and center, the PFA is applied on the echo data iteratively to search the optimization solution based on minimum entropy criterion. The accurate rotation angle and center are obtained when the minimum entropy of the ISAR image is achieved. The golden section search method is used in the iteratively processing to reduce the computational load. The MTRC of the ISAR image is compensated by using the optimized parameters and the ISAR image can be best focused. The effectiveness and robustness of the proposed algorithm are demonstrated by simulated and real data.

9252-26, Session PS

Frequency invariant beamforming under bandpass sampling based on convex optimization

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I. INTRODUCTION

Beamforming is a spatial filtering technique for receiving signals illuminating an array of sensors from some specific directions, whilst attenuating signals from other directions. As higher frequency and lager bandwidth has been utilized in many real platforms especially in the field of radar and electronic reconnaissance systems, wideband beamforming has been studied extensively in the past decade.

For wideband signals, there exists phase difference between sonsor outputs because wideband signals consist different frequency components. For a fixed aperture, the spatial resolution of a beamformer is proportional to frequency. Our purpose is to obtain the nearly identical beam response for wideband signals getting through the array of sensors. Such beamformers are independent of frequency, they are often called frequency independent beamformers or frequency invariant beamformers (FIBs).

Many literatures have considered and promoted various methods to solve this problem. Among these methods, the class of optimization method is the main stream. Wideband beamformer is implemented by a group of FIR filters after each sensor and the coefficients of FIR filters are obtained through the optimization process.

II. PROBLEM DESCRIPTION & METHODS

A commom assumption is made that these algorithms handle the receiving signals by Nyquist sampling, but we are acquainted with that signals are often bandpass sampled getting through the sensors and transformed to the base band through the digital down conversion(DDC) processing in many practical systems. After the DDC processing, the signals are passed to the FIR beamformer. The bandpass sampling and DDC alter the signal expression and make the objective function different compared with signals under Nyquist sampling. The main difference induced by bandpass sampling and DDC is the implementation resource consumption under the identical desired beam pattern, in detail the FIR beamformer cost more taps to achieve the same beam pattern under bandpass sampling.

In this paper, the effect caused by bandpass sampling and DDC is addressed and analyzed in detail; through convex optimization toolbox a strategy to deal with this circumstance is proposed; the formulation of such convex optimization problem is presented.

III. RESULTS & CONCLUSIONS

A comparison has been made between two kinds of sampling procession to achieve FIB beamforming. The effect caused by bandpass sampling and DDC is addressed and analyzed in detail for wideband beamforming. Simulation results show that the method proposed in this paper is effective in dealing with FIB problem under bandpass sampling.

9252-27, Session PS

Terahertz superconducting hot electron bolometers: technological issues and predicted mixer performance for Y-Ba-Cu-O devices

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High-Tc superconducting (HTS) hot electron bolometers (HEB) are a promising alternative to moderately cooled THz Schottky diode mixers due to their large expected bandwidth (tens of GHz), and low local oscillator (LO) power requirements (tens of microwatts) at 60-80 K operating temperature. As for low-Tc superconducting (LTS, e.g. Nb or NbN) HEB mixers, it is mandatory to grow very thin high quality HTS epitaxial layers leading to good micro or nano-bolometer superconducting properties. The challenge for Y-Ba-Cu-O resides in the chemical reactivity of the material and the related aging effects.

Early HEB models, based on the point bolometer approach, described the device in terms of thermal reservoirs only, namely the electrons and the phonons of the superconductor. The electron-phonon interaction time, which drives the HEB mixer ultimate response, is 1-2 ps for Y-Ba-Cu-O, with a resulting bandwidth close to 100 GHz (so far unobserved), whereas it is about 20 ps for NbN. Recently, we introduced the hot spot model (previously used for LTS HEBs) for Y-Ba-Cu-O HEBs, taking the spatial dependence of the electron temperature along the nano-bolometer (or constriction) length into account. For Y-Ba-Cu-O, however, HTS specificities (large phonon thermal conductivity and heat capacity; long film to substrate phonon escape time) render the hot spot model implementation more complicated, because the phonon temperature spatial dependence also intervenes.

From DC analysis, the I-V characteristics were deduced and compared to published Y-Ba-Cu-O constriction data. The steady state analysis allowed determining the mixer performance (conversion gain G and noise temperature Tn). For a 100 nm long x 100 nm wide x 10 nm thick constriction at 9 microwatt LO power, the expected double sideband (DSB) Tn = 1520 K (G = -13.7 dB). For a larger 400 nm x 400 nm x 35 nm constriction, Tn = 1210 K DSB at 35 microwatt LO power (G = -13.1 dB). This latter device is more realistic according to our current HEB fabrication process and Y-Ba-Cu-O aging effects. Whereas the few microwatt LO power – as required by the smaller device - can be achieved with solid state multiplier

sources, the few tens of microwatts LO power – as required by the larger device - can be achieved with THz quantum cascade laser sources.

Model improvements were sought in two directions. Firstly, we represented the constriction DC resistivity vs. temperature superconducting transition – initially described by a Fermi-Dirac type fitting function – by a more realistic variation deduced from experimental measurements. Secondly, the frequency dependence of the Y-Ba-Cu-O resistivity was introduced to evaluate the mixer bandwidth. The impact of this dependence is twofold, as affecting the thermal balance in the device, but also the impedance matching between the constriction and the planar antenna to which it is connected. All these effects will be discussed in terms of both small signal direct detection and heterodyne mixing.

This work is part of the MASTHER project (Miniaturized All Solid-state Terahertz HEterodyne Receiver), supported by the French national research agency (ANR) under contract # 2011 BS03 008 01.

9252-28, Session PS

Investigations on time stability of passive THz imaging

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Terahertz radiation is within the frequency range from 100 GHz to 10THz. This radiation has specific characteristics in terms of imaging. The radiation is harmless to the human body because the energy transferred by electromagnetic waves in this range of frequencies are very small thus there is no ionization of matter.

The development of imaging devices and exploration of new spectral bands is a chance to introduce new equipment for assuring public safety. It has been proved that objects hidden under clothing can be detected and visualized using terahertz (THz) cameras. However, passive THz cameras still offer too low image resolution for objects recognition.

In order to determine the properties of terahertz imaging for detection of hidden objects several aspects need to be considered. During the scanning the object is hidden under human's clothing for a specified period of time, the object might be heated by the energy from the human body. Taking into account the fact that the image captured by the terahertz camera reflects the spatial distribution of the relative temperature of the observed objects, the effect of the measurement time on the imaging capabilities should be examined. A very important aspect is the influence of the type (material composition) of coating material, as well as the type of an object hidden under clothing (size and material).

One of the most important factors that may affect the possibility of imaging and detection in the terahertz range is humidity in the atmosphere. The water vapor particles reduce the transmission of THz radiation in the atmosphere.

The purpose of the studies is to investigate the time stability of passive THz imaging for detection of concealed objects. In the article, we present the measurement setup, the measurement methodology as well as the initial results of measurements with various types of clothing and test objects.

9252-29, Session PS

Sparse ISAR imaging using 2D compressed sensing

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Radar imaging is an ill-posed linear inverse problem and compressed sensing (CS) has been proved to have tremendous potential in this field. This paper surveys the theory of radar imaging and a conclusion is obtained that the processing of ISAR imaging can be denoted mathematically as a problem of 2D sparse decomposition. Based on CS, we propose a novel observing strategy for ISAR imaging radar and utilize random sub-sampling in both range and azimuth dimensions, which will reduce the amount of sampling data tremendously. In order to handle 2D reconstructing problem, the ordinary solution is converting the 2D problem into 1D by Kronecker product, which will increase the size of dictionary and computational cost sharply. In this paper, we introduce the 2D-SL0 algorithm into the reconstruction of imaging. It is proved that 2D-SL0 can achieve equivalent result as other 1D reconstructing methods, but the computational complexity and memory usage is reduced significantly. Moreover, we will state the results of simulating experiments and prove the effectiveness and feasibility of our method.

9252-30, Session PS

A novel image registration method for InISAR imaging system

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Inverse synthetic aperture radar (ISAR) can generate 2D high resolution images for none cooperative targets in a long distance, which is particularly useful for military and civilian applications. The ISAR image is the Range-Doppler plane projection of 3-D spatial target which may result in the loss of structure information. In order to enhance the target recognition, the interferometric ISAR (InISAR) technique is proposed to achieve the third dimension of the target. For space targets in stable movements, the scale of the ISAR image in the cross range direction can be easily obtained. Therefore, it is possible to use two antennas to obtain the third dimension.

In practical applications, the wave path difference caused by the separately placed antennas will lead to the mismatching between ISAR images. In order to implement the interferometric processing to the same scattering point of different ISAR images, image registration should be carried out firstly, since registered images are the preconditions in InISAR systems. Existing InISAR image registration methods are based on the parameters estimation of the target's angular motion. The method transforms the problem of image registration to the parameter estimation of target's angular motion. In practical application, the difference of the system structures limits its extension. Furthermore, the approximation introduced in the modeling makes the offset not be completely compensated.

Aiming at the image registration problem in InISAR system?we propose a new method based on grade-by-grade matching. In visualization, the mismatching of ISAR image mainly consists of offset in range and Doppler direction. We can carry out image registration by find the corresponding location of each strong scatterer in the two obtained ISAR images. By our method, the computation and registration precision are both perfect. We can sum up the approach of the entire image registration algorithm as follows:

1) Obtain two ISAR images, denoted by A and B, using coherent processing.

2) Extract strong scatterer centers (SSCs) of each ISAR image by using OSTU algorithm.

3) Calculate the centroid of each ISAR image according to the SSCs.

4) A rough translation is made according to the difference between the obtained centroids. .

5) Search the biggest correlation between the two ISAR images in a particular range, and where the optimal match is achieved.

6) Mapping the SSC in A and B based on the optimal match to get the ROI.

7?Search all the possible matching points in the ROI. If more than one point exist, the one with the maximum correlation is selected.

8) Export the SSCs and the matching values respectively to accomplish the image registration.

In order to verify the theoretical analysis and the proposed image registration algorithm, the InISAR signal processing simulation of a target with stable motion in the far-filed is made, and the proposed InISAR image registration algorithm is tested accordingly. The range profiles and Doppler profile obtained from the two antennas using the traditional method cannot be matched. The mismatching in the range and Doppler direction affects the interferometric result of the two complex ISAR images. After image registration using the proposed technique, the locations of each scattering point are well reconstructed. Hence, simulation results confirm the effectiveness of the proposed method.

9252-18, Session 4

Investigation of the CLEAN deconvolution method for use with Late Time Response analysis of multiple objects *(Invited Paper)*

Simon J. Hutchinson, Manchester Metropolitan Univ. (United Kingdom); Christopher T. Taylor, The Univ. of Manchester (United Kingdom); David A. Andrews, Michael J. Fernando, Nicholas J. Bowring, Manchester Metropolitan Univ. (United Kingdom)

This paper investigates the use of the CLEAN non-linear deconvolution method for resolving multiple Late Time Response (LTR) targets in concealed object detection. When a conductive object is illuminated by a signal with an Ultra-Wide band (UWB) signal, surface currents develop across the object and give rise to LTR responses which are re-radiated to the transceiver. The LTR frequency components contained in these signals are dependent on and unique to the geometry of the illuminated target. The experimental results of the LTR signal from targets including a 12 cm steel rod, a 13 cm kitchen knife, a replica small revolver and a replica semi-automatic pistol are presented. Composite targets made up of pairings of the objects stated previously are also presented.

The LTR signal has been obtained using a Vector Network Analyser (VNA) connected to two horn antennas configured in a pseudo-monostatic arrangement. The standoff range used for all the targets scanned is 2 metres and the bandwidth of the frequency sweep is 0.5 GHz to 40 GHz. This wide range provides improved frequency resolution and allows for greater control of the maximum range of the system. The data extracted for processing is the horizontal cross-polar S21 parameter provided by the VNA. An optimised experimental setup is discussed in order to determine the most effective method in which to obtain the LTR signal.

A comparison between a linear deconvolution technique and the CLEAN method is provided. This is followed by a discussion of the merits of each technique along with the details of the algorithms used to produce them. Simulated finite element analysis results for the objects are presented for comparison with the deconvolved experimental results obtained under laboratory conditions. Wavelet analysis techniques including the Continuous Wavelet Transform (CWT) have been considered for use in obtaining further information and improving discrimination between multiple targets found within the same environment.

The extracted Complex Natural Resonance (CNR) data from the LTR signal is analysed in post processing using a Generalized Pencil-Of-Function (GPOF) method. The data obtained by this method includes the frequency, decay time and amplitude components of the target poles. The results of the GPOF method are processed using a neural network to provide classification of the objects detected. The results of this are presented and discussed with comparison to alternative classification regimes.

9252-19, Session 4

Faster with CLEAN – An exploration of the effects of applying a non-linear deconvolution method to a novel radiation mapper

Matthew J. Southgate, Manchester Metropolitan Univ. (United Kingdom); Christopher T. Taylor, The Univ. of Manchester (United Kingdom); Simon J. Hutchinson, Nicholas J. Bowring, Manchester Metropolitan Univ. (United Kingdom)

This paper examines the suitability and potential of reducing the acquisition requirements of a novel radiation mapper through the application of the non-linear deconvolution technique, CLEAN. The radiation mapper generates a threshold image of the target scene, at a user defined distance, using a single pixel detector manually scanned across the scene . To date, the mapper has been used to measure, with and without a horn antenna, the beam pattern of a focused radiation source at 75GHz. From first principles, the effort required to implement an application-specific version of CLEAN is significant. This paper provides a discussion of the factors involved and merits of incorporating this specific signal processing method into the system. Details of early development work and experimental results for the radiation mapper are available in Southgate and Bowring, IEEE 32769.

In this paper we describe the modifications to the system for the generation of an intensity map and the relationship between resolution and acquisition time for a specific target scene. The factors influencing image fidelity and the minimum observational requirements for this scene are identified and discussed. The variation of the above parameters impact the fill-factor of the final intensity image, which in turn determines the ability of the operator to accurately identify features of the radiation source within a target scene.

The CLEAN algorithm and its variants have been extensively developed by the radio astronomy community to improve the image fidelity of data collected by sparse interferometric arrays. CLEAN was originally designed by Hogbom for use with far-field imagery consisting of uncorrelated point sources on an approximately uniform background. However, the algorithm has demonstrated surprising adaptability to a wide range of astronomical targets, including extended sources with a smooth distribution. CLEAN has also been successfully applied to terrestrial imagery, as detailed in Taylor et al. SPIE 9078-19 and Bose et al., IEEE 2002.

CLEAN can be applied directly to raw data via a bespoke algorithm. However, this investigation is a proof-of-concept and thus requires a well tested verification method. We have opted to use the public ally available implementation of CLEAN found in the Common Astronomy Software Applications (CASA) package. This software package is the de-facto standard in radio astronomy for image processing. The use of CASA for this purpose dictates the use of simulated input data and radio astronomy standard parameters. The preparatory work described herein enables the generation of a representative simulation for testing.

Finally, this paper presents the results of applying CLEAN to our simulated target scene, with a discussion of the potential merits a bespoke implementation would yield.

9252-20, Session 4

Design and verification of half-pixel for linear multipixel THz imaging systems

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For linear multi-pixel imaging systems, a linear stack of pixels comprising of an antenna and a heterodyne receiver are needed. Such pixels can be realized using MMIC processes. The main constraint for such multi-pixel system is a compact

array of pixels giving high coupling to quasi-optics used for focusing. This paper addresses this trade-off and presents a novel solution based on beam synthesis of two consecutive subarrays.

One such sub-array along with heterodyne receiver is described as half-pixel in this paper and it is realized using 2x4 patch array and Gilbert core sub-harmonic mixer using a 250nm DHBT process. The patch array has ohmic loss better than 8 dB and mixer conversion loss is 6-8 dB over 320-350 GHz RF band.

The chip size is 1mm x 2mm and therefore for 7 simultaneous beams a MMIC of 8 half-pixels is foreseen.

9252-21, Session 4

New opportunities for quality enhancing of images captured by passive THz camera

Vyacheslav A. Trofimov, Vladislav V. Trofimov, Igor E. Kuchik, Lomonosov Moscow State Univ. (Russian Federation)

We demonstrate new opportunities for the detection of concealed objects and of clothes components due to using of computer processing of images captured by passive THz cameras, manufactured by various companies. Computer processing of images results in a temperature resolution enhancing of cameras. In particular, we demonstrate new possibilities for seeing the clothes details, which raw images, produced by the THz cameras, do not allow to see.

We consider images produced by THz passive cameras manufactured by Microsemi Corp., and ThruVision Corp., and Capital Normal University (Beijing, China). In the report, the images, captured by infrared cameras, are discussed also with the aim of demonstration of their new opportunities if we apply a computer processing of these images.

9252-22, Session 4

Detection algorithm of big bandwidth chirp signals based on STFT

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Aiming at solving the problem of detecting the wideband chirp signals under low Signal-to-Noise Ratio (SNR) condition, an effective signal detection algorithm based on Short-Time-Fourier-Transform (STFT) is proposed. Considering the characteristic of dispersion of noise spectrum and concentration of chirp spectrum, STFT is performed on chirp signals with Gauss window by fixed step, and these frequencies of peak spectrum obtained from every STFT are in correspondence to the time of every stepped window. Then, the frequencies are binarized and the approach similar to mnk method in time domain is used to detect the chirp pulse signal and determine the coarse starting time and ending time. Finally, the data segments, where the former starting time and ending time locate, are subdivided into many segments evenly, on which the STFT is implemented respectively. By that, the precise starting and ending time are attained. Simulations shows that when the SNR is higher than -28dB, the detection probability is not less than 99% and false alarm probability is zero, and also good estimation accuracy of starting and ending time is acquired. The algorithm is easy to realize and surpasses FFT in computation when the width of STFT window and step length are selected properly, so the presented algorithm has good engineering value.

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9253-1, Session 1

A picosecond laser FAIMS analyzer for detecting ultralow quantities of explosives

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The development of laser-based techniques for detecting explosive and other dangerous compounds in air gives attractive opportunities in increasing the sensitivity of detection. So, the recent advances in creation of laser ion sources for field asymmetric ion mobility spectrometry (FAIMS) allowed to achieve the TNT detection threshold about 3 . 10-15 g/cm3 for a portable detector1.

Here, we used state-of-the-art picosecond chip Nd3+:YAG laser to elaborate a method for detecting ultra-low quantities of explosives both in air and traces from surfaces. The method combines the FAIMS technique with the laser ionization of air sample and the laser desorption of analyzed molecules from the surveyed surfaces. The radiation of the fourth harmonic (? = 266 nm, ?pulse=500 ps, Epulse=20 -150 ?J, ?= 50-300 Hz) was applied. The efficiency of ionization for trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX), pentaerythritol tetranitrate (PETN) in dependence on the mean laser power, peak intensity, frequency and pulse energy was investigated. It is shown that optimal value of the peak intensity should not be less than 5. 106 W/cm2 whereas the increasing the mean laser power between 15-25 mW always means the greater sensitivity. The results of detecting for TNT, RDX, PETN vapors under these conditions shows 2-3-fold growth of detected ion signals for each of explosives tested under nanosecond excitation1.

The laser desorption regime in FAIMS analyzer was developed by use of exiting laser beam outside the detector through deleting a special plug. The results of detection of TNT, RDX and PETN are presented.

The applied chip Nd3+:YAG laser has a little radiating part and consumed electric power 25 W. The detection threshold of the developed picosecond laser FAIMS portable analyzer of explosives can be estimated as (1÷3). 10-15g/cm3 for TNT vapors and 40 pg for TNT traces.

References

[1] Kotkovskii G.E., Sychev A.V., Tugaenko A.V.; et.al. A laser spectrometer of field asymmetric ion mobility. Instruments and experimental techniques, 54 (2), 256-261 (2011).

9253-2, Session 1

Eye-safe UV Raman spectroscopy for proximal detection of explosives and their precursors in fingerprints concentration

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Because of its unique ability to identify molecular species in a fast and non-destructive way Raman spectroscopy is a laser-based technique gaining increasing consideration in the fight against terrorism or organized crime, particularly in the identification of illegal substances, even in trace amounts, such as explosives or drugs. However, although the Raman spectra of explosives are available for most of these substances, by only a few years this method has been also considered and promisingly developed for detection of explosives in traces at distances of meters or tens of meters, in such a way to be eligible as an early warning of a terroristic attack.

This is because the main problem of Raman spectroscopy is the inherent weakness of the signal emitted from the sample and the interference induced by the competitive phenomenon of luminescence that in many cases hide the Raman signal.

Even more difficult is the development of a Raman device able to work in eye-safety conditions, so that the laser beam cannot damage the eye in case of accidental pointing. This poses further and more severe limits on the maximum energy density for each single laser shot.

These drawbacks can be overcome using a laser excitation in the ultraviolet region of the spectrum because it is well known that the Raman signal is amplified proportionally to the inverse of the fourth power of the laser wavelength (the so-called “(1/lambda)4” rule) [1].

In this work we present the results of a pulsed stand-off Raman system capable of detecting explosives with surface density from 1 mg/cm2 down to 100 ?g/cm2 at a distance from 7 to 10 m. The system consists of a frequency-quadrupled Nd:Yag laser (wavelength 266 nm), of 10 ns pulse duration, aligned with a 12” mirror in a co-axial geometry. The mirror is directly coupled with an optical fibers bundle to collect light into a 320 mm focal length spectrometer and, finally, on a low light imaging CCD camera. The explosives were analyzed with a single laser shot whose energy density was fixed at 3 mJ/cm2, below the maximum permissible exposure (MPE) for the human eye within this wavelength and pulse duration [2].

Although many systems are claimed to detect explosives at greater distances and comparable or lower concentrations, to our knowledge very few are optimized to ensure safe conditions for the human eye in case of accidental pointing of the laser beam. In these frameworks we will show the results obtained on different types of explosives (Pentaerythritol tetranitrate, PETN, trinitrotoluene, TNT, urea nitrate, UN) and explosives precursors (Ammonium nitrate, AN), also used in improvised explosives devices (IED), deposited on samples of common fabrics, to simulate a light stain released by a single fingerprint on a common garment. The sensitivity and selectivity of the system will be discussed in terms of limit of detection (LOD) for each chemical compound and receiver operating characteristics (ROC curves).

9253-3, Session 1

Infrared reflectance spectra: effects of particle size, provenance and preparation

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As opposed to simple molecular absorption spectra, the reflectance spectra of solids are influenced by a number of factors including the sample preparation method, the origin of (mineral) samples and also the method of preparation, e.g. loose powders vs. pressed pellets. In an effort to originally compare or derive some standards for reflectance spectroscopy, we have investigated some of these parameters and the effects they have quantitative reflectance spectra,

particularly in the longwave infrared. In the infrared, spectral features may be observed as either maxima or minima: In general, upward-going peaks in the reflectance spectrum result from surface scattering, i.e. rays that are reflected from the surface without bulk penetration, whereas downward-going peaks are due to either absorption or volume scattering, i.e. rays that have penetrated or refracted into the sample interior and are not reflected. The light signal reflected from solids usually encompasses all these effects, but these include dependencies on particle size, morphology and sample density as well as origin. This paper measures the reflectance spectra in the 1.3 – 16 micron range for various bulk materials that have a combination of strong and weak absorption bands in order to observe the effects on the spectral features as a function of several parameters including: a) the mean grain size of the sample. Bulk materials were ground with a mortar and pestle and then sieved to separate the samples into various size fractions: 0-45, 45-90, 90-180, 180-250, 250-500, and >500 microns. Also, b) samples were studied as a function of loose powders versus pressed pellets, and c) for select minerals we also observe significant change depending on the origin of the sample. All were studied by recording the directional-hemispherical spectra using an integrating sphere attached to a Fourier transform infrared spectrometer. Our observations clearly show that all three effects have very substantial effects on the measured reflectance spectra for bulk materials.

9253-4, Session 1

Real-time criteria based on spectral dynamics of medium response for the detection and identification of substance using THz signal

Vyacheslav A. Trofimov, Svetlana A. Varentsova, Lomonosov Moscow State Univ. (Russian Federation)

We propose effective criteria based on analysis of spectral dynamics of medium response for the detection and identification of dangerous substance at using pulsed THz signal. These criteria are integral criteria in time.

We apply these criteria for the detection of explosive for various situations. Among them, we consider the complicated shape of the PWM C4 explosive and a compound explosive. We show also the applicability of these criteria for drugs distinguish and for drugs detection in the mixture with neutral substances.

9253-5, Session 1

Handheld detector using NIR for bottled liquid explosives

Hideo Itozaki, Hideo Sato-Akaba, Osaka Univ. (Japan)

Bottled liquid is not allowed in the security regions in the airport, because it is possible that terrorists might use liquid explosives which cannot be detected well now. Some detectors are proposed, but none of them has been accepted to the airport security.

Here, a handheld detector of bottled liquid explosives using NIR has been developed. It is very powerful to detect all kind of liquid explosives. It is so compact and light, so it is easy to introduce it to the security gate so on.

This equipment has a small light to illuminate a bottle and the transmitted light through the bottle is captured by the inlet of light guide at another side of the bottle. The captured light is guided by light guide to the tiny spectrometer. The spectra from wavelength of 0.5-1.0 micron is analyzed by a small microchip and compared with the spectra of many liquid data, and decided the checked sample is safe or dangerous. The result is indicated LED light, red or green. It needs less than one second to indicate the results. As it works with a battery, it is so compact and can be handled by hand easily. It works so well in our laboratory scale. We are planning to make is its feasible test and looking forward to installing it to many security checks.

9253-6, Session 1

Detection of hidden objects using a real-time 3D millimeter-wave imaging system

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The region of the electromagnetic spectrum bounded by microwaves at the lower frequencies and far-infrared at the higher frequencies forms the mm and sub-mm band or terahertz (THz) band, numerically defined as frequencies from 100 GHz to 10 THz. THz wavelengths have several properties that can promote the use of THz imaging as a security imaging tool for recognition of hidden objects, dangerous materials, aerosols, imaging through walls as in hostage situations, and also in bad weather conditions. There is no known ionization hazard for biological tissue, and atmospheric degradation of THz radiation is relatively low for practical imaging distances.

We recently developed a new technology for the detection of THz radiation. This technology is based on very inexpensive plasma neon indicator lamps, also known as Glow Discharge Detector (GDD), that can be used as very sensitive THz radiation detectors. Using them, we designed and constructed a Focal Plane Array (FPA) and obtained recognizable2-dimensional THz images of both dielectric and metallic objects. A common use of THz imaging for security purposes is in body scan booths. Most of the body scan machines can only detect the metal object hidden beneath the clothing. Using THz wave it is shown here that even concealed weapons made of dielectric material can be detected. An example is an image of a knife concealed inside a leather bag and also under heavy clothing. Three-dimensional imaging using radar methods can enhance those images since it can allow the isolation of the concealed objects from the body and environmental clutter such as nearby furniture or other people. Using the current technology, conventional frequency-modulated continuous-wave (FMCW) radar for THz waves requires the use of expensive microwave mixers and Low Noise Amplifiers (LNAs). A uniquely simple and inexpensive solution is presented using the very inexpensive Glow Discharge Detectors (GDDs). The use of GDDs enables direct heterodyning between the electric field of the target signal and the reference signal eliminating the requirement for expensive mixers, sources, and LNAs. Whole body imaging machines using THz/mm waves are used at airports around the word. The reason that those machines are not widely used by other security organization is the high system cost. It is shown here that it is possible to significantly reduce the system cost by using the GDD. This reduction of system cost can make it possible for use by smaller security organizations and in other applications.

We expanded the ability of the FPA so that we are able to obtain recognizable 2-dimensional THz images in real time. We show here that the THz detection of objects in three dimensions, using frequency modulated continuous wave (FMCW) principles is also applicable in real time. This suggested system presented here employs chirp radar method so that each point on the object corresponds to a point in the image and thus it includes the distance information. This imaging system is also shown here to be capable of imaging objects from distances allowing standoff detection of suspicious objects and humans from large distances.

9253-8, Session 1

Possibility of the detection and identification of substance at long distance at using broad THz pulse

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We investigate the influence of various opaque barriers placed before the object on THz signal reflected from object. As a barrier, we consider a bag, made from thick paperboard and containing various substances; many layers of thin papers (paper napkin for computer monitor); various clothes, plywood, newspaper, purse, bag and other materials. Measurements are made at room temperature and humidity about 50%. The aim of investigation is the detection of a substance under real conditions. We discuss new features of the detection of a substance covered under various ordinary materials and possible way for their influence deleting on the detection by using reflected THz pulse. We find out that at long distance, the position of objects, that reflects the THz pulse, influences the measured spectrum. Other very important features of the measurements with the multilayer paper are the strong modulation of the spectrum of the reflected signal.

9253-9, Session 1

Towards a “fingerprint” of paper network; separating forgeries from genuine by the properties of fibre structure

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We have presented a new way to identify postal stamp forgeries and counterfeited banknotes, by separating these from genuine originals analysing differencies in the underlying paper fibre networks. We have used here our recently developed method, which is based on curvelets, for measuring the fibre orientation distribution. With this method the main orientation direction and anisotropy of the orientation can be measured accurately. We have also defined a new parameter, which we call pinhole percentage. This parameter kind of describes the porosity and goodness of the paper grade. Furthermore, we have used fibre thickness as one parameter where it is statistically relevant. Using these parameters we have shown that it is possible to separate forgeries from genuine originals in 2D-or 3D-parameter space by using proper quantities for identification. Even the different series of genuine banknotes could be divided in their own regions in the parameter spaces.

In the analysis of stamps we used North-Ingria pictorial (series II) stamps, which are quite common and both genuine originals and forgeries are easy to purchase. These stamps were issued in 1920 when this region encountered a small period of effort to independency, and it, among other things, issued two series of own stamps. The real postal use of these stamps was very short and all cancellations are made in Kirjasalo (which was located in Finland). However, the leftovers were sold, and that is why uncancelled (mint) stamps are quite common. For some reason forgeries of the pictorial series II are also very common. This is maybe because forgers thought that these issues may be valuable as philatelic objects for stampcollectors.

For banknote analysis we used ten counterfeited 50 euro banknotes, and two different series of 30 pieces of unused original banknotes. These two series were printed on the paper provided by different manufacturers. The counterfeited banknotes were provided for us by the Finnish National Bureau of Investigation, and the original banknotes by the Bank of Finland.

Although we use here banknotes and stamps as an example we believe that similar method can be applied for investigation of other valuable papers and documents. Our final goal is to define a “fingerprint” of paper networks which could be used to build a reference storage for the use of counterfeit recognition.

9253-10, Session 2

Stand-off detection and classification of CBRNe using a Lidar system based on a high power femtosecond laser

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Vigilance against CBRNe (Chemical, Biological, Radioactive, Nuclear, and explosive) materials is indispensable not only in defense applications, but also in more general security measures such as counter terrorism. Especially for aerosol materials, stand-off detection and classification are considered to be essential for early warning, evacuation, protection, and diffusion prediction in wide areas. Quite a variety of measurement techniques have so far been developed for aerosol monitoring. In consideration of the diversity of aerosol types that might be encountered under various situations, however,, it would be highly desirable if detection and classification of various aerosol types can be achieved with an integrated lidar system.

This work focuses on applications of Laser Induced Breakdown Spectroscopy (LIBS), and two-photon fluorescence (TPF) methodologies using a high-power (terawatt) femtosecond laser to achieving stand-off detection and classification of various aerosols over distances of several hundred meters to a few kilometers. When applied to stand-off measurements, femtosecond lasers have advantages over conventional nanosecond lasers in terms of higher sensitivity. This is because of the generation of low-temperature and spectrally high-contrast plasmas: in addition, long focusing distance can be attained in association with filamentation, a nonlinear phenomenon due to extremely high peak power of femtosecond laser pulses.

Nanosecond lasers, on the other hand, are superior to the femtosecond counterparts in the ease of handling, cost, and durability. Thus, we propose a hybrid system that combines nanosecond and femtosecond lasers. Under normal situations, a Mie scattering lidar based on a near infrared nanosecond laser monitors aerosols in the area. Once this lidar detects unusual aerosol clouds, the femtosecond laser is irradiated, and the detection and classification of the aerosol component are attempted. To substantiate this basic concept, we have conducted various laboratory experiments on the stand-off detection of simulant materials. For the R and N detection schemes, cesium chloride aerosols have successfully been detected by LIBS using a high-power femtosecond laser with wavelengths 800 nm, output power 200 mJ, and pulse width of 35 to 1000 fs. For the B detection scheme, TPF signals of organic aerosols such as riboflavin have been clearly recorded

using a high-power femtosecond laser with wavelengths 800 nm, output power of 30 mJ, and pulse width of 100 to 1000 fs. In the experiment, we focused the femtosecond laser loosely onto an aerosol cloud that was generated by spraying aqueous solution of the material. The LIBS and TPF signal was detected with a 20 cm diameter telescope at the stand-off distance of about 10 m. Spectra were detected with a spectrometer equipped with an ICCD camera. In addition, a compact femtosecond laser with wavelengths 780 nm, output power of 1 mJ, and pulse width of 120 fs, has been employed for the LIBS classification of organic plastics (e simulants). Finally, the properties of signals observed in these laboratory experiments are exploited for the system parameter consideration of a future field model that will enable the CBRNe detection under actual outdoor environments.

9253-11, Session 2

Multi-channel thermal infrared communications using engineered blackbody radiation for security applications

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The thermal (emitted) infrared frequency bands, typically from 20-40 THz and 60-100 THz, are best known for applications in thermography, such as target acquisition, surveillance, night vision, and remote sensing. This unregulated part of the spectral range offers opportunities for the development of short-range secure communications. The 'THz Torch' concept was recently presented. This technology fundamentally exploits engineered blackbody radiation, by partitioning thermally-generated spectral noise power into pre-defined frequency channels. The energy in each channel is then independently pulsed modulated, transmitted and detected, creating a robust form of short-range secure communications in the far/mid infrared.

The basic 'THz Torch' architecture for short-range secure wireless communications has a transmitter, a receiver, two identical optical band-pass filters and a back-end processing circuit. For convenience, this transmitter employs five miniature incandescent light bulbs, connected in series, having its thermal noise power (generated from blackbody radiation) channel-filtered by the optical band-pass filter with a transmission range from 25-50 THz. At the receiver, the incoming band-limited noise power is again filtered by a matching channel filter. A pyroelectric infrared (PIR) sensor is employed to convert the thermal energy into voltage output. The output signal voltage passes through the back-end processing circuit which consists of a low-noise amplifier (LNA), a band-pass filter (BPF) and a Schmitt trigger. To date, limited experimental results of sub-kbps single-channel 'THz Torch' links have been presented.

This concept can be further extended by implementing multiplexing schemes, which can offer important benefits, including increased overall end-to-end data rates (with band-limited channels) and higher levels of security. Multi-channel 'THz Torch' frequency division multiplexing (FDM) and frequency-hopping spread-spectrum (FHSS) schemes were briefly introduced, but only slow 40 bps FDM system was demonstrated. In our multi-channel implementations, each channel was similar to the one used in the single-channel system. Four commercial off-the-shelf (COTS) filters were employed to define four non-overlapping frequency bands within the thermal infrared, covering the range from 10-100 THz. In addition, more channels involving more filters are possible to overcome limited response times for a single PIR sensor.

Here, we report an improved FDM implementation with a much faster data rate of 1,280 bps. When compared to our previously reported proof-of-concept FDM demonstrator, reasons for the x32 improvement in data rate include the use of (1) faster PIR sensors, (2) noise cancelling using dual-PIR sensors and (3) improved low noise post-processing electronics. Furthermore, an experimental FHSS demonstrator is shown for the first time, having a 320 bps data rate. With this proof-of-concept FHSS scheme, the end-to-end serial data stream is transmitted into the same channels as for the FDM system, but only within one channel at any time – dictated by pseudo-random channel allocation. To compare channel quality with such multiplexing schemes, bit error rate (BER) analysis is performed for bias currents from 44-80 mA and transmission distance from 1-5 cm. With both 4-channel multiplexing schemes, measured BERs of < 10^-6 are achieved over a distance of 2.5 cm for an 80 mA bias current.

By exploring a diverse range of methods, significant enhancements to both data rate and distance can be expected. Our thermodynamics-based approach represents a new paradigm in the sense that 19th century physics can be exploited with 20th century multiplexing concepts for low-cost 21st century ubiquitous security and defence applications in the thermal infrared range.

9253-12, Session 2

Complex of the new generation of the instrumental analytical approaches to prevent bioterrorism dangerous

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The problem with bio-warfare has existed for a long time and the real manifestations of its action were during local military conflicts only. More recently, there have been attempts by terrorist organizations to implement bio-warfare. The attention of many scientists is concentrated today on the very important question: how to prevent non-desirable consequences and to preserve the life and health of people. The analysis shows that the permanent decisions should be directed to providing reliable express control and on the development of the effective measures to remove destructive effects of bio-warfare. In this presentation the main approaches which exists today for the revealing some toxic and inflectional agents are analyzed. The main attention is given to the application of a system for the new generation of the instrumental devices based on the principles of biosensors for rapidly revealing step by step: total toxicity of environmental objects, appropriate groups and the exact chemical substances present in them. Simple and rapid estimation of the total toxicity through the control of the intensity of chlorophyll fluorescence (IChF) by the direct or remote ways by the device "Floratest" (Ukraine) will be demonstrated. There is a possibility on the basis of IChF curve of growing plants from some territory during appropriate period to reveal the appearance of toxic substances in this area. Their presence in more local cases may be done with the using bioluminescent bacteria (pure Ukrainian strains) or/ and controlling chemiluminescence of short term Daphnia living medium. For accomplishing the mentioned analysis it was developed a special portable chemiluminometer. To revea some group toxic elements (as a rule phospororganic types) the electrochemical enzymatic biosensors based on the cerium oxide ISFETs are recommended. The last one, as well as optical devices, is based on the SPR ("Plasmotest", Ukraine), porous silicon (with the registration of biospecific interaction macromolecules by luminescence or electro conductivity) and some nano-metal oxides were realized in immune biosensors at the determination of content of the number of micotoxins (T2, patulin, aflatoxin, searelenone and others), some microorganisms (Salmonella spp.) and diagnostics of viral disease (retroviral leucosis). The main characteristics of the above mentioned devices will be presented and we will some conformation that the sensitivity of all analysis meets the requirement in respect of controlling contamination of environmental objects by toxins and bacteria at the minimal permissible level. Overall the time of analysis does not exceed

half hour and in most of cases it is within the 10 min timeframe. Moreover, application of these approaches is very simple and may be realized under field conditions.

9253-13, Session 3

Track-based event recognition in a realistic crowded environment

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To improve security, the number of surveillance cameras is rapidly increasing in crowded environments, such as shopping malls, airports and railway stations. However, the number of human operators remains limited and only a selection of the video streams are observed. Automatic detection of suspicious behavior in CCTV cameras can help to handle the huge amount of data. Suspicious behavior can be characterized by small-scale subtle and obvious actions, large-scale walking patterns and interactions between people. For example, pickpocketing can be recognized during several steps of the criminal incident. Sometimes, it is possible to detect the actual snatch, by analyzing actions at a small scale. On the other hand, it may be easier to detect (a group of) pickpockets while they are following the victim or when they are interacting with each other, by analyzing actions at a larger time scale. There are several approaches to detect small-scale actions by analyzing local motion. This paper focusses on event recognition by detecting large-scale track-based patterns.

Our event recognition method consists of several steps: pedestrian detection, object tracking, track-based feature computation and rule-based event classification. In the experiment, we focused on single track actions (walk, run, loiter, stop, turn) and track interactions (pass, meet, merge, split), because they are related to activities of pickpockets that may lead to a distinction between suspicious and normal behavior. The experiment includes a controlled setup, where 10 actors perform these actions. The method is also applied to all tracks that are generated in a crowded shopping mall in a selected time frame. The results show that most of the actions can be detected reliably (on average 90%) at a low false positive rate (1.1%), and that the interactions obtain lower detection rates (70% at 0.3% FP). This method may become one of the components that assists operators to find threatening behavior and enrich the selection of videos that are to be observed.

9253-14, Session 3

Automatic detection of suspicious behavior of pickpockets with track-based features in a shopping mall

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Proactive detection of imminent incidents is required to decrease the cost of security and of security incidents. The number of surveillance cameras is rapidly increasing to improve security in crowded environments, such as airports, shopping malls and railway stations. However, the number of human operators remains limited, only a selection of the video streams can be observed and the effectiveness of predictive behaviour indicators is not clear. Automatic early detection of suspicious behavior in CCTV cameras can help to prevent incidents in a timely manner and handle the huge amount of data. This paper focusses on the automatic detection of suspicious behavior of collaborating pickpockets, because this illustrates the predictive value of social behavior indicators. This is extremely challenging because the environment is crowded, people move freely through areas which cannot be covered by a single camera, because the actual snatch is a very subtle action, and because collaboration is complex social behavior. Pickpockets demonstrate typical kinds of behavior before, during and after the actual incident. Examples of this behavior are: following an intended victim, or – in the case of cooperating pickpockets – interacting with each other for coordination or for handing over the loot. Our approach focusses on the walking and interaction patterns with track-based features. Based on a camera plan and an expectation of people density we predict the quality of these features, and the performance of automatic detection of collaborating pickpockets.

Our method consists of several steps: pedestrian tracking, feature computation and pickpocket recognition. We performed an experiment with 18 actors that performed in total more than 20 validated pickpocket incidents in a crowded shopping mall. We used a top-down approach to translate expert knowledge in features and rules, and a bottom-up approach to learn discriminating patterns with a classifier. The classifier was used to separate the pickpockets from normal passers-by that are shopping in the mall. We performed a cross validation approach to train and evaluate our system. In this paper, we describe our method, identify the most valuable features, and analyze the results that were obtained in the experiment. We estimate the quality of these features, and the performance of automatic detection of (collaborating) pickpockets.

9253-15, Session 3

Some observations on computer lip-reading: moving from the dream to the reality

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In the quest for greater computer lip-reading performance there are a number of tacit assumptions which are either present in the datasets (high resolution for example) or in the methods (recognition of spoken visual units called ``visemes'' for example). Here we review these and other assumptions and show the surprising result that computer lip-reading is not heavily constrained by video resolution, pose, lighting and other practical factors. However, the working assumption that visemes are the best unit for recognition does need further examination. We conclude that visual units which were defined over a century ago are unlikely to be optimal for a modern computer lip-reading system.

9253-16, Session 3

Finding suspects in multiple cameras for improved railway protection

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Railway stations, airports and shopping centers are subject to large impact threats such as explosives in left-luggage. Frequently, these locations are also stage for small criminal activities, such as graffiti, vandalism, theft from passengers, physical and verbal abuse against passengers and staff, sexual harassment, and trespassing. The negative impact of

these events can be minimized, and the suspect can be held accountable if he can be found quickly after the incident. Localizing suspects after incidents requires time from the operator and careful attention. Especially if the operator loses track of the suspect - e.g. he enters a shop and leaves through another exit - and he has to find the individual at another time and location. Support for localizing the suspect quicker and more efficiently is therefore of economic value for security operators in the rail station, airport or retail setting.

This paper describes a demonstration of our tracking system at a railway station in Poland. Our tracking technology supports an operator in finding suspects interactively after an event occurs, with proven operator-efficiency and speed improvement [5]. The integration and demonstration of this system was done in the EU FP7 project PROTECTRAIL. Among other tasks in this project, TNO has provided the security operator with a support system for tracking individuals. This system was live demonstrated to a group of stakeholders in October 2013 in Zmigrod, Poland. The experiment showed that the system allows fast interactive retrieval of an individual by showing only similar candidates. An operator can find the origin or destination of a person more efficiently, especially over large time and space intervals.

9253-17, Session 3

A photogrammetric approach for real-time 3D localization and tracking of pedestrians in monocular infrared imagery

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Target tracking within conventional video imagery poses a significant challenge that is increasingly being addressed via complex algorithmic solutions. The complexity of this problem can be fundamentally attributed to the ambiguity associated with actual 3D scene position of a given tracked object in relation to its observed position in 2D image space. We propose an approach that challenges the current trend in complex tracking solutions by addressing this fundamental ambiguity head-on.

This work investigates the accuracy of classical photogrammetry, within the context of current target detection and classification techniques, as a means of recovering the true 3D position of pedestrian targets within the scene. Based on photogrammetric estimation of target position, we then illustrate the efficiency of regular Kalman filter based tracking operating on actual 3D pedestrian scene trajectories.

In contrast to prior work in the field, we leverage the key advantages of thermal-band infra-red (IR) imagery for the pedestrian localization?. We show that the robust localization and foreground target separation, afforded via such imagery, facilities accurate 3D position estimation to within the error bounds of conventional Global Position System (GPS) positioning. However, here this is achieved using passive sensing from a conventional infra-red imaging camera, with no a priori environment calibration.

Combined with prior work on target detection and human behaviour analysis we present the real-time detection, tracking and behaviour reporting of human targets, localized to global scene position, via true 3D pedestrian tracking in a given environment. Results are presented using a conventional thermal-band (IR) sensor arrangement where individuals are tracked over a range of evaluation scenarios.

Example Videos: http://www.durham.ac.uk/toby.breckon/demos/sapient/

9253-18, Session 3

Advantages of fused night vision in complex urban environment

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Industry has been focussed on techniques and technology required to achieve fused systems that meet current Size, Weight And Power (SWAP) requirements. This paper looks at both the overall technical approaches along with the user requirements and demands.

Today both Thermal Imaging (TI) and Image intensifiers (I2) are widely used by military and para-military forces throughout the world. The benefits and limitations of both are widely understood. What is less well understood are the drivers for more fused systems and the areas in which they offer benefits to the user community.

Field data and examples:

It is important to understand the situations where fusion will offer advantages over existing technologies. Currently most users have head mounted I2 for basic night mobility and TI or I2 for weapon mounted sights.

Camouflage:

It is relatively easy to defeat current in-service I2 systems. As these devices rely on amplification of the star or moonlight available there are corresponding shaded areas that do not benefit from this light source.

Example 1: shows an individual at around 5 meters from the observer. The target has crouched against a broken background provided by a small bush and is shaded from the moonlight. Addition of the thermal channel allows clear and reliable detection of this individual.

Low light:

In scenarios where the user needs to enter and search buildings the ambient light levels are often low enough to render the I2 channel ineffective. It is obviously possible to use IR illumination to overcome this limitation. However, Light in this wavelength can readily be detected by technology as simple as the humble mobile phone camera and prevents truly covert operation.

Example 2: Transition from outside urban environment to the inside of a farm building with a large opening door. Again the absolute light levels available are low enough to render the I2 system ineffective. By combining the two systems the user has good situational awareness outside the building and gains all the benefits of the high spacial resolution provided by I2 combined with the ability to image the individuals when inside the building.

High dynamic range:

In complex urban environments there are a large number of potential light sources. The high dynamic range of these images limits the ability of the I2 to image objects in deep shadow. Adversaries can take advantage of this limitation to hide in plain view. It is important to understand that in many cases the absolute light level in the shaded areas is well within the range that the I2 can operate in. It is the high dynamic range between the two areas the I2 cannot accommodate.

9253-19, Session 3

Generalized Hough Transform-based time invariant action recognition with 3D pose information

David Muench, Wolfgang Huebner, Michael Arens, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

The problem of human action recognition has emerged as an important field in the computer vision community due to its large number of applications such as automatic video

surveillance, content based video-search and human robot interaction. In order to cope with the challenges which this large variety of applications present, recent research has focused more on developing classifiers able to detect several actions in more natural and unconstrained video sequences.

The invariance discrimination tradeoff in action recognition has been addressed by utilizing a Generalized Hough Transform. As a basis for action representation we transform 3D poses into a robust feature space, referred to as pose descriptors. For each action class a one dimensional temporal voting space is constructed. Votes are generated from associating pose descriptors with their position relative to the end of an action sequence. Training data consists of hand-segmented action sequences. In the detection phase valid human 3D poses are assumed as input, e.g. originating from 3D sensors or monocular pose reconstruction methods. The human 3D poses are normalized to gain view-independence and transformed into (i) relative limb-angle space to ensure independence of non-adjacent joints or (ii) geometric features. In (i) an action descriptor consists of the relative angles between limbs and their temporal derivatives. In (ii) the action descriptor consists of different geometric features. In order to circumvent the problem of time-warping we propose to use a codebook of prototypical 3D poses which is generated from sample sequences of 3D motion capture data. This idea is in accordance with the concept of equivalence classes in action space. Results of the codebook method are presented using the Kinect sensor and the CMU Motion Capture Database. The contribution of this paper is a quantitative evaluation of (i) and (ii) on live and recorded data. First results show robust and time-invariant action recognition.

9253-20, Session 4

Sensor for real-time determining the polarization state distribution in the object images

Barbara N. Kilosanidze, George Kakauridze, Institute of Cybernetics (Georgia); Yuri Mshvenieradze, Georgian Technical Univ. (Georgia)

An innovative real-time polarimetric method is presented based on the integral polarization-holographic diffraction element developed by us. This element is suggested to be used for real time analysis of the polarization state of light, to help highlight military equipment in a scene. In the process of diffraction, the element decomposes light incoming on them onto orthogonal circular and linear basis. The simultaneous measurement of the intensities of four diffracted beams by means of photodetectors and the appropriate software enable the polarization state of an analyzable light (all the four Stokes parameters) and its change to be obtained in real time. The element with photodetectors and software is a sensor of the polarization state. Such a sensor allows the point-by-point distribution of the polarization state in the images of objects to be determined. The spectral working range of such an element is 530 – 1600 nm. This sensor is compact, light-weight and relatively cheap, and it can be easily installed on any space and airborne platforms. It has no mechanically moving or electronically controlled elements. The speed of its operation is limited only by computer processing. This sensor is proposed to be use for the determination of the characteristics of the surface of objects at optical remote sensing by means of the determination of the distribution of the polarization state of light in the image of recognizable object and the dispersion of this distribution, which provides additional information while identifying an object. A theoretical model showing the connection of the Stokes parameters of light reflected from a recognizable object with the characteristics of the material of the reflecting surface of the object has been developed that allows the appropriate correlation connections to be set. Experimentally the possibility of obtaining the distribution of the values of the Stokes parameters is shown for the samples from different materials and of a different geometric form. The possibility of detection of a useful signal of the predetermined polarization on a background of statistically random noise of an underlying surface is also possible with presence of appropriate database. The application of such a sensor is also considered for the determination of the distribution of stressed state in different constructions based on the determination of the distribution of the polarization state of light reflected from the object under investigation. A compact laboratory model was developed for the realization of this method. The correlation relations between the change in the polarization state of light reflected from the sample with the distribution of the dosated mechanical stresses is considered. The theoretical model is developed. The experimental results are shown for different samples with stress distribution from different materials both transparent and opaque, metals and dielectrics. The method is nondestructive and will enable the distance monitoring and diagnosis of already existing constructions and objects to be carried out that is important for the prevention of natural disasters. In comparison with existing methods of nondestructive stress analysis the proposed method will differ by universality, simplicity, technological effectiveness, high speed and comparative cheapness, which conditions its competitiveness.

9253-21, Session 4

Fusion of optical flow based motion pattern pattern analysis and silhouette classification for person tracking and detection

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This paper presents a novel approach to detect and track persons in video by combining optical flow based motion analysis and silhouette based recognition. A new fast optical flow computation method is described, and its application in a motion based analysis framework unifying tracking and human detection. We perform experiments on the state-of-the art VIRAT surveillance dataset, which has been split in a train set and a test set, used for evaluation of our methods only.

We distinguish humans from other objects by analyzing the underlying motion using optical flow. Our optical flow algorithm represents optical flow by grid based motion vectors, which are computed very efficiently and robustly by using horizontal and vertical scan lines applying template matching. A tracking framework using Kalman filtering has been implemented efficiently by predicting the future location of an object using the estimated optical flow vectors.

For optical flow based motion analysis we model the motion patterns of the tracked human and non-human objects by the positions, velocities, motion magnitudes, and motion directions of their optical flow vectors, and we train a random forest classifier on the VIRAT train set with these features. For recognition the random forest computes a normalized score measuring the similarity of a track to a human track.

The silhouette analysis method starts with computing a pixel-based motion image for each frame in the video. The detected moving objects are represented by image blobs. Using edge detection the silhouettes of these image blobs are computed. Finally, these silhouettes are classified as human or non-human by a comparison with silhouettes from the CASIA gait database with 1102 examples of persons. For each silhouette a score is computed which is a measure for the similarity of a silhouette with the human silhouettes from the CASIA gait database. A normalized score measuring the similarity of a track to a human track is obtained by accumulating the similarity measures of the silhouettes in the track.

The optical flow classification and the silhouette classification are used as a combined classifier measuring similarity to a human by the sum of the optical flow classifier and the silhouette classifier. We apply ROC curve analysis to set different decision thresholds on the recognition score for different scenarios, which offers the user the opportunity to trade off false alarms against high recognition rates.

The experiments on the VIRAT test set demonstrate that for human detection the combination of the optical flow based motion method with one based on human silhouette analysis, obtains superior results, compared to the individual methods.

9253-23, Session 4

Distinguishing suspicious actions in long-distance surveillance

Guy Hebe, Eli Chen, Yitzhak Yitzhaky, Ben-Gurion Univ. of the Negev (Israel)

Human action classification distinguishes different human behaviors at a video signal. Suspicious behavior can be defined by the user, and in long distance imaging it may include bending the body during walking or crawling, in contrast to regular walking for instance. The terms “action” usually refers to a simple movement pattern, typically performed by a single person for a short period of time (e.g. walking, swimming, jumping etc.).

Previous methods for human action recognition dealt in general with standard signals, in which the object of interest is relatively close to the camera, and therefore fairly clear and easily distinguished from the surrounding environment. This makes it easier to capture detailed information regarding the object and the action it is performing, thus having many possibilities in developing methods to recognize different actions and obtaining action properties.

However, when imaging is performed through relatively long distance (one or two kilometers and above) additional difficulties occur which affect the performances of these tasks, since the captured video signals are likely to be degraded by the atmospheric path. The degradation sources that include turbulence and aerosols in the atmosphere cause blur in the images, and in video sequences spatiotemporal-varying distortions caused by turbulence become also meaningful. Both of these degradation sources may significantly reduce the ability to automatically acquire and understand the behavior of moving objects. Two main reasons for that are: (i) Since the objects in the video frames are distorted (blurred), the spatial and structural characteristics of the moving objects may be considerably changed, and thus be less informative for higher-level image processing operations such as classifying their actions into categories. (ii) The time-varying image shifts caused by the turbulence induce additional movements in the scene (temporal clutter), which may increase the false alarm (false detection) rate and also add distortions to the shapes of the objects. These effects become more significant as the imaging distance increases and as the sizes of the objects of interest in the image are smaller.

The images of objects in imaging through a distance of over one or two kilometers are usually relatively small. In such cases, the range of actions that can be resolved is more limited, particularly atmospheric effects. This process of action recognition is usually a part of surveillance system that naturally includes a detection of the moving objects as a first step, followed by tracking them in the video sequence. Surveillance may also include object classification/recognition and finally action/behavior recognition. Pre-processing operations such as image quality improvement (i.e., restoration, de-noising and frame registration) may also a part of the process, mainly as the video signal is degraded by atmospheric effects).

In this study, we examine dynamic spatio-temporal (motion and shape) characteristics of correctly detected moving objects in long-distance horizontal imaging. According to such characteristics, we construct features that characterize different actions for these imaging conditions. Human movement characteristics are created for both atmospherically-degraded signals and non-degraded signals. Then, we distinguish suspicious from non-suspicious actions, based on these characteristics.

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9253-30, Session 5

Biopolymeric lasers *(Keynote Presentation)*

Jaroslaw Mysliwiec, Lech Sznitko, Konrad Cyprych, Adam Szukalski, Andrzej Miniewicz, Grzegorz Pawlik, Antoni C. Mitus, Wroclaw Univ. of Technology (Poland); François Kajzar, Ileana Rau, Univ. Politehnica of Bucharest (Romania)

Bioderived and bioinspired materials are of current interest because they can provide novel, attractive physical properties while being produced by “green” technologies and being also biodegradable.

Here we present experimental results of studies on the amplified spontaneous emission, stimulated emission, lasing and random lasing phenomena observed in biopolymeric systems based on: pure deoxyribonucleic acid (DNA), modified DNA with cationic surfactant, gelatinized starch and doped with well-known laser dyes like rhodamine 6G, DCM or derivatives of pyrazoline.

We show that light amplification thresholds and photostability for studied systems are comparable to other polymers and could be very useful as fully functional materials in photonics applications, opening the way of designing completely biological photonic devices.

9253-31, Session 5

Linear and NLO properties of DNA-CTMA-SBE complexes *(Invited Paper)*

Ana-Maria Manea, Ileana Rau, François Kajzar, Univ. Politehnica of Bucharest (Romania)

The deoxyribonucleic acid (DNA) was first functionalized with the surfactant cetyltrimethylammonium (CTMA) and after with sea buckthorn extract (SBE) at different concentrations. The sea buckthorn extract used for this study was obtained from dry sea buckthorn berries. Solvent extraction using hexane and supercritical CO2 are the main methods used for sea buckthorn oil extraction. The complexes were processed into good optical quality thin films by spin coating on different substrates such as: glass, silica and ITO covered glass substrates. SBE contains many bioactive substances that can be used in the treatment of several diseases, such as cardiovascular disease, cancer, and acute mountain sickness [1]. The obtained thin films were characterized for their spectroscopic, fluorescent, linear and nonlinear optical properties as function of SBE concentration. The third-order nonlinear optical (NLO) properties of thin films were determined by the optical third-harmonic generation technique at 1 064.2 nm fundamental wavelength. The thin film refractive indices were determined by the Fabry-Perot (FP) interferences.

9253-32, Session 5

Protein-based artificial receptive field *(Invited Paper)*

Yoshiko Okada-Shudo, The Univ. of Electro-Communications (Japan)

We are aiming to develop the artificial visual receptive field using a photosensitive protein bacteriorhodopsin (bR).

BR has been studied toward realising protein-based artificial retinas, since it is similar in its function to visual pigment rhodopsin.

Light excitation of bR photocell generates transient positive and negative photocurrents when an incident light is turned on and off.

We consider the positive and negative responses as the excitatory and inhibitory regions of visual receptive field,

We fabricated cortex simple cell receptive field, DOG filter, and demonstrated edge detection.

9253-33, Session 5

Design and development of variable data security holograms on photopolymer and biomaterials *(Invited Paper)*

Sheeja M. K., Sree Chitra Thirunal College of Engineering (India)

Commercial markets for security holograms are increasing day by day. Inexpensive embossed holograms are nowadays widely applied to protect valuable products and documents. For example, credit cards are embedded with holograms, to prevent card forgery. Also, compact discs, books, magazines, computer software, cosmetics, dress materials, watches, sporting goods, stationary, business cards, tickets, clothing hangtags, certificates, passes, currency, passport etc. are protected by using embossed holograms. Security holograms belong to the group of Diffractive Optical Variable Image Devices (DOVIDs). They offer high potential to fight against counterfeiting and provide product authenticity. They can be produced only through expensive, specialized and technologically advanced equipments. They are considered secure because photocopiers, scanners or standard printing techniques cannot replicate them.

Security holograms currently enjoy rapid penetration in the market place and they contain fixed data content. Due to rapid advancements in digital imaging techniques, look-alike holograms can be made easily. The present paper aims to develop methods for producing machine-readable holograms with variable data content. The variable data content will offer additional security and since they are machine-readable the originality can be proved using computer software. For producing machine-readable holograms, holographic variable data storage system has to be designed and developed. The paper describes recording variable data security holograms on Photopolymer and biomaterial.

Holographic data storage systems are demonstrated already and they are meant for high-density data storage on disc shaped material and are quite expensive. For the present work, we designed a holographic variable data storage system to incorporate variable data content in each security holograms. The system is cost effective and produces holograms on real time Photopolymer strip and on biomaterial strip continuously. The recorded holograms are machine-readable and the reconstructed data pages are to be processed in a computer for verification.

9253-34, Session 6

Optical biosensor system for the quick and reliable detection of virus infections: VIROSENS *(Invited Paper)*

Guenther Proll, Anja Hartjes, Alexander Sinclair, Goran Markovic, Florian Pröll, Biametrics GmbH (Germany);

Pranav Patel, Matthias Niedrig, Robert Koch-Institut (Germany)

Viral infections are of special threat because they can induce severe courses of disease but only few medical treatments are available. Because of socio-economic and climate changes, increased worldwide mobility and population growth, the risk of newly occurring and quickly spreading viral pathogens has been increased. A diagnosis of these diseases at an early stage is essential for a quick risk assessment and a proper health management as well as patient's treatment in an optimal way. Currently, the diagnosis of such diseases is based on time consuming and costly detection methods that can only be performed by specially trained personnel in laboratories at specific security levels.

9253-35, Session 6

Photo-assisted chemical sensors *(Invited Paper)*

Corrado Di Natale, Yuvaraj Yuvaraj Sivalingam, Gabriele Magna, Roberto Paolesse, University of Rome Tor Vergata (Italy)

The prospect of tailoring the physicochemical properties of semiconductors paves the way to a fascinating scenario to develop ad-hoc materials for specific applications. In this regard, the surface coverage of solids with either organic or inorganic sensitive layers is a common method to provide new sensing properties without compromising the bulk features.

Concerning organic-semiconductor coupling; a large number of metal-oxides have been functionalized with a variety of organic molecules such as polymers, phthalocyanines, porphyrins and biological elements. Among them, the combination of ZnO nanorods and porphyrins is particularly interesting because of the electron transport properties and the facile immobilization of these molecules onto the semiconductor surface.

Porphyrins are widely used as elements of sensor arrays because of the variety of chemical interactions that occur with the volatile compounds. Furthermore, the structure-sensitivity relationship is rather well known. On the other hand, zinc oxide provides the possibility to fabricate ordered vertical structure with high surface/volume ratio by a simple and low-cost procedure.

The conductivity of porphyrins coated ZnO nanorods is influenced both by adsorbed molecules and visible radiation and that the exposure to white light greatly enhances the gas sensitivity and selectivity. Many factors can be tuned in order to improve the ultimate performance of this hybrid material such as the porphyrins structure or the crystal plane orientation of semiconductor surface. For example, we shown that the metal ion coordinated to the porphyrin influences the photovoltage under different chemical environments.

In general, the architecture of porphyrin arrangement plays a crucial role in the diffusion and solubility properties of analytes. In particular, if the sensitive dye does not completely cover the underlying surface this effort could result vain. In this context, solution coating does not always provide a uniform coverage of the ZnO surface and as a consequence the potentialities of the porphyrin-ZnO material are not fully exploited. To overcome this problem, a one-pot hybrid material growth recipe where porphyrins are added directly to the precursor solution of the hydrothermal method have been introduced.

Adsorption properties can be adequately studied measuring the Contact Potential Difference (CPD) with the Kelvin probe when the material is exposed to organic compounds in dark and under white illumination. The variation of the CPD shows that the illumination with visible light enhances the response to reducing agents while in casting coated material the enhancement can be observed only for strongest electron donor molecule.

The same concept can also be applied to the detection of compounds in liquid phase. Porphyrins coated ZnO electrodes have been applied in a amperometric setup to measure cysteine. Under illumination a consistent reduction of the peak potential an increase of sensitivity and a better selectivity with respect to similar compounds are observed.

These results are promising for the development of novel generations of chemical sensors where the light is used to modulate the selectivity and the sensitivity in order to increase the discrimination power of sensor arrays.

9253-36, Session 6

Rapid and label-free screening and identification of anthrax simulants by surface enhanced Raman spectroscopy

Antonia Lai, Salvatore Almaviva, Valeria Spizzichino, Antonio Palucci, ENEA (Italy); Lorella Addari, ENEA (Italy); Domenico Luciani, Sandro Mengali, Consorzio CREO (Italy); Christophe A. Marquette, Institut de Chimie et Biochimie Moléculaires et Supramoléculaires (France); Ophélie Berthuy, Institut de Chimie et Biochimie Moléculaires et Supramoléculaires (France); Bartlomiej Jankiewicz, IOM Univ. (Poland); Luigi Pierno, SELEX ES S.p.A. (Italy)

During the last years, Surface Enhanced Raman Spectroscopy (SERS) has become an recognized analytical technique. That is due to two main factors: the development of in-field portable compact Raman platforms by many manufacturers and commercialization of reliable and spatially homogeneous (over large areas) SERS-active substrates. That allowed to use SERS for routine analysis. Additionally, micro-Raman spectroscopy is a well known fast and sensitive tool for the detection, classification, and identification of biological microorganisms. It needs no sample preparation, it is non-invasive and non-destructive and, therefore, it can be used on living organisms, the negligible absorption and weak Raman scattering of water allow to use it with aqueous solutions and, above all, the Raman spectrum of a substance is highly specific and can provide a chemical fingerprint of several samples. All these characteristics make the Raman spectroscopy a good candidate as a sensor tool for environment automatic monitoring systems.

Raman spectroscopy has already been demonstrated capable to detect and discriminate among different biological agents, bacteria species and, even, between different strains of the same kind of bacterium.

Within of the RAMBO project (Rapid-Air Monitoring particle against biological threats) the feasibility of an unattended SERS sensor for biological threats detection was explored, in particular, for Anthrax detection, both as vegetative cells and endospores.

For this purpose was selected Bacillus thuringiesis as simulant of Bacillus anthracis.

The possibility to bind selectively the bacteria by means of properly selected bacteriophages immobilized on an active SERS substrate was also investigated. Phages receptors are highly selective and reactive towards specific bacteria and they can withstand water or air environments without losing their binding capabilities.

The functionalization of commercially available SERS substrates has been successfully accomplished with a fairly good and reliable fill factor.

The sensing surface was also characterized with standard micro-Raman equipments in order to assess the background Raman features. The Raman measurements have been carried out both with low (10 X) and high (100 X) magnification in order to differentiate between average and local features. Moreover, the measure time has always been limited to less than 1 minute in order to assess the feasibility of a fast response.

The same characterization have been performed also on samples with vegetative cells and endospores of B. thuringiensis randomly dispersed on the same SERS substrates.

Scanning electron microscopy (SEM) was also used to

characterize the substrates, with and without spores or bacteria, helping to assess the effective immobilization of target.

Although functionalized substrates exhibits a structured and highly interfering Raman signal, the modification of the Raman spectrum after exposure to the B. thuringiensis can be exploited to provide an early warning of the bacillus presence. This behavior will allow to foresee the use of SERS as an effective and fast technique for early warning of biological threats in a detector designed against biological threats.

Conversely, biohazard pathogens bacteria (Bacillus anthracis) have been investigated implementing the SERS technique in the frame of the project RAMBO (Rapid-Air Monitoring particle against Biological threats) funded by EDA (European Defense Agency) Join Investment Program on CBRN protection.

Results and comparisons will be presented and discussed not only in Security but contaminants, additives or adulterants in goods and food have been included due to the importance in market consumers every day (e.g. botulism toxin in canned foods).

9253-48, Session 6

Devices for in-situ and proximal detection of biohazards, food contaminants and explosive compounds: results from national and international security projects *(Invited Paper)*

Antonio Palucci, ENEA (Italy)

Nowadays Homeland Security (HS) has become an issue worldwide recognized as a strong societal challenge, as indicated in the last EU Horizon2020 framework, because from the 9/11 events, any nation's infrastructure have shown the extreme vulnerability against a well prepared and effectively performed terroristic attack.

Public transportation has been around for about 150 years, but terroristic attacks against buses, trains, subways, etc., is a relatively recent phenomenon, increasingly attractive target from 1970 for terrorists as well as places where large crowds congregate are prime targets of opportunity for suicide bomber attacks.

A suicide attack is usually performed with an IED (improvised explosive device), which can come in many forms ranging from a small pipe bomb to a sophisticated device that can contain explosive materials or contaminants (biohazards).

To this respect, the need for new, reliable and effective instrumentations for explosive and precursor detections at trace levels for homeland security applications raised strongly from the community that is now more prone to review his rights thus to reconsider some ethical aspects in the next future.

In this context accurate, fast and relatively simple methods of analysis to be implemented in early detection of suspicious materials (e.g. biohazards, contaminants and/or explosives) is essential to ward off disease outbreak and dispersion in the environment for countering terrorism and organized crime, but also an appealing challenge for basic and applied research.

The Diagnostic and Metrology (DIM) Laboratory has contributed to the development of new monitoring tools, and to investigate in new nanostructured materials, with its background in spectroscopy field, in EU, NATO and in national projects.

Among the detection technologies investigated and implemented by DIM, Raman-based spectroscopy has recently gained consents as potential tool for the detection of explosives at a certain distance due to recent technical improvements and also a high selectivity for a uniquely identification of the substance in a interfering background.

Raman spectroscopy, and in particular the Surface Enhanced Raman Spectroscopy (SERS) technique, has recently attracted the attention on homeland security for the capability in the identification of microbial and bioagents detection (small particle detection).

Nanostructured materials have been investigated in order to increase the sensitivity of the Raman signals in order to be integrated in a final compact device. Performances of gold nanopillars of 35 nm diameter and length of about 200 nm, thermally or E-beam evaporated gold substrates have been compared with commercial on the shelf products in the frame of the EU Security project BONAS (Bomb discovery technologies), in order to reach high selectivity and sensitivity in explosive detection.

9253-38, Session 7

NLO properties of formyl-methoxy derivatives of [2.2] paracyclophane containing the donor group in different positions *(Invited Paper)*

Lada N. Puntus, Institute of Radio Engineering and Electronics (Russian Federation) and A.N. Nesmeyanov Institute of Organoelement Compounds (Russian Federation); Kyrill Y. Suponitsky, Dmitrii Y. Antonov, A.N. Nesmeyanov Institute of Organoelement Compounds (Russian Federation); Irina Pekareva, Kotel'nikov Institute of Radio Engineering and Electronics (Russian Federation); Konstantin A. Lyssenko, A.N. Nesmeyanov Institute of Organoelement Compounds (Russian Federation); François Kajzar, Institut des Sciences et Technologies Moléculaires d'Angers (France)

Organic molecules emerged as very interesting class of materials for the application in devices based on second order NLO effects. They exhibit high polarizability and fast, electronic in origin, NLO response. Moreover for many applications based on second order NLO effects the materials to be used have to lack center of symmetry. Chiral molecules form a class of materials which are par excellence noncentrosymmetric. [2.2]paracyclophanes (PCP) is composed of two benzene rings covalently fixed in a face-to-face geometry by ethano bridges. The strained and stacked structure allows one to hold substituents in close proximity and to utilize the interaction between two aromatic "desks" for the charge transfer. On the other hand, pCp derivatives could be planar chiral, central chiral or combine in their structure several chiral elements that give rise to a wide range of chiral molecules most of which could be obtained in enantiomerically pure form. Thus a large number of pCp derivatives can meet the requirements to be noncentrosymmetric and chiral. All this makes this class of compounds very promising for the purposes of nonlinear optical material developments.

Formyl-methoxy derivatives of [2.2]paracyclophane (pCp) have been synthesized and studied by optical spectroscopy as well as the X-ray diffraction method. Some of these molecules crystallize in acentric space groups and, therefore, can exhibit SHG. The efficiency of SHG ability which was measured by the powder technique at 1064 nm fundamental wavelength and average NLO susceptibility for some of studied molecules was found comparable with a such well-known NLO crystal as PNP. The calculations of molecular and crystalline nonlinearities within density functional theory using M052X/6-31+G* level of approximation were also conducted for the considered series of compounds. The results obtained have revealed that family of the formyl-methoxy derivatives of [2.2]paracyclophane might be of interest for a potential nonlinear optics application.

9253-39, Session 7

Pyrazoline derivatives for random laser operation *(Invited Paper)*

Lech Sznitko, Adam Szukalski, Konrad Cyprych, Andrzej Miniewicz, Wroclaw Univ. of Technology (Poland);

Jaroslaw Mysliwiec, Wroclaw Univ of Technology (Poland)

Pyrazoline based materials possess many interesting features that can be used in medicine as an active agent of drugs composition, but also in nonlinear optics and in emission spectroscopy[1-3].

We present our recent studies on synthesis and development of new types of pyrazoline derivatives that exhibits broadband photoluminescence. The use of pyrazole ring can create highly conjugated system that allows charge to be transferred from acceptor to donor group. By changing donor and acceptor groups it is possible to engineer the luminescent properties of obtained molecules. What is very interesting, nonlinear optical properties, can also be tuned by different pyrazoline ring substitution, forming very attractive class of multifunctional materials. Moreover we report on successful random laser operation that can be obtained for oversaturated matrices containing different type of pyrazoline derivatives. Aggregation of pyrazoline derivatives can lead to creation of nanocrystal clusters that efficiently scatter the light and introduce random feedback into the system.

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9253-40, Session 7

A review of materials for spectral design coatings in signature management applications *(Invited Paper)*

Kent E. Andersson, The Swedish National Defence College (Sweden); Christina Åkerlind, Swedish Defence Research Agency (Sweden)

As Swedish Military focus is again widened from recent years focus on force protection in asymmetric expeditionary scenarios, to include national security, there is a clear orientation towards effect and mobility. Mobility is often achieved at the expense of less armour and the decreasing capability for force protection is in turn compensated with active EW-systems and means for camouflage and deception – i.e. signature management systems. This development together with a rapid development in multi spectral sensor technology adds to the utility of developing advanced materials for spectral design in signature management applications. The need to camouflage soldiers is high in any event, and the requirement to do both expeditionary missions and being prepared for national protection scenarios drives the need for adaptive signature of platforms. A literature study was performed, probing the databases Web of Science, Scopus, CSA and SPIE for civilian and military advancements on potential materials, or spectral design coatings, for signature management applications. Qualitative text analysis was performed using a six-indicator instrument. The indicators where: spectrally adaptable reflectance; low gloss and; low degree of polarization; low infrared emissivity; non destructive properties in RADAR and in general controllability of optical properties. Identified materials and coating designs are presented with relevant performance metrics. They are categorized into pigment or periodic surface structures. The latter is further divided into subcategories in the order of increasing complexity: multilayers, i.e. one-dimensional structures, photonic bandgap materials and lastly nano- and biomimic materials. The military utility of the coatings is assessed qualitatively. The need for developing a framework for assessing the military operational benefit of incrementally increasing the performance of spectrally selective coatings is identified.

9253-41, Session 7

Analysis of key properties of materials for optical power limiting and the influence of nonlinear scattering *(Invited Paper)*

Michael Körber, Adrian Azarian, Bastian Schwarz, Bernd Eberle, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

The quality of passive optical power limiters strongly depends on the nonlinear characteristics of the materials used. While numerous kinds of limiting materials have been investigated, suspended nanoparticles, especially gold and silver nanoparticles, have attracted attention due to their strong nonlinearity. We propose to study the origin of this nonlinear behavior in two different regimes: At high fluences, induced scattering has been observed to have a major influence, which is believed to be due to thermal effects. The second regime is located near the critical fluence, where currently no satisfying model exists to predict the properties of potential materials. This is quite problematic, as actual passive optical limiters do not perform well enough to provide reliable eye safety. Thus, new ways have to be found to come closer to this goal.

To understand the origin of the critical fluence values, we propose to use statistical methods, based on principal component analysis, to identify the important material properties responsible for the critical fluence limit. The results could be used to find new optical limiting materials with a lower critical fluence value.

Additionally, we make use of numerical calculations to simulate the optical limiting of suspended nanoparticles caused by nonlinear scattering. In order to study the thermal heating around the irradiated nanoparticles we use the finite elements method. It gives insight into the temporal size evolution of induced scattering centers. This also allows us to calculate the influence of Mie scattering on optical limiting and its dependence on material properties. A comparison of simulated results with experimental ones leads to a further understanding of the interaction between different limiting mechanisms.

Combined, these two approaches have the potential to improve the general understanding of the actual processes involved in optical limiting. We discuss the implications of our results for the design of a passive optical limiter.

9253-42, Session 7

Chalcogenide glass with good thermal stability for the application of molded infrared lens *(Invited Paper)*

Ju Hyeon Choi, Young Jun Park, Du Hwan Cha, Jeong Ho Kim, Hye-Jeong Kim, Korea Photonics Technology Institute (Korea, Republic of)

An interest of chalcogenide glass has been increased because of their use in preparing optical lenses in range of 3-12 ?m. With recent advance in less costly uncooled detector technology, moldable lens using chalcogenide glass has drawn a great deal of attention. In this study, amorphous Ge-Sb-Se chalcogenide was prepared by a standard melt-quenching technique. Melted chalcogenide glass for moldable lens should have unique thermal mechanic properties in order to be applied to molding process. Specifically, the Ge:Sb ratio were controlled in order to find out the most stable glass forming area.

Thus, the optical, thermal and thermo mechanical properties to find out right composition were characterized by IR transmission spectroscopy, DSC (Differential Scanning Calorimeter) and TMA (Thermo Mechanical Analysis), respectively. The moldability of chalcogenide glass was

characterized through transcription properties of the mold's surface. The relations between thermal properties and the moldability were studied using thermal properties such as Tg and Tx as function of mean coordination number i.e composition ration between Ge and Sb. In addition, both IR transmittance and x-ray diffraction patterns of the molded chalcogenide glass lens were evaluated to verify the compositional and structural stability of the glass material under the given molding conditions. Finally, the preferential Ge:Sb ratio in Ge-Sb-Se based chalcogenide glasses was selected for producing moldable lenses.

9253-37, Session 8

Novel electrode systems for amperometric sensing: the case of titanium. *(Invited Paper)*

Fabio Terzi, Laura Pigani, Chiara Zanardi, Barbara Zanfrognini, Stefano Ruggeri, Giulio Maccaferri, Renato Seeber, Univ. degli Studi di Modena e Reggio Emilia (Italy)

After working for years on organic materials, e.g., polythiophenes and the relevant composite, we shifted our attention to unusual metals, chosen as candidates to effective amperometric sensing on the basis of the atomic structure and crystalline properties. The present contribution aims at proposing an electrode material very rarely employed in electroanalysis, namely Ti. We have experimented that the peculiar nature of Ti leads to electrochemical behavior quite different with respect to the conventional electrode materials.

As to the nature of Ti electrodes, a very thin layer of TiOx spontaneously forms on Ti surface when in contact with the atmosphere or aqueous solution. The properties of this layer are very different with respect to TiO2, which has been widely employed as electrode material in electroanalysis, mainly in the form of particles and nanoparticles. Moreover, electrode coatings based on TiO2 reported in the literature are often multicomponent materials: additional components, such as metal nanoparticles or enzymes, are anchored to the oxide surface and represent the portion of the electrode system in charge of detecting the analytes through redox reactions occurring on their surface, TiO2 acting as a mere suitable support.

Our work focuses on the determination of strong oxidizing species and noble metal ions. Strong oxidising species are commodity chemicals employed in a number of different applications, such as cellulose pulp and textile bleaching, treatment of drinking and waste waters, and synthesis of inorganics and organics, whose concentration level should be monitored in the industrial processes. We developed analytical procedures for the determination of the hydrogen peroxide at high concentration values, at different pH value, based on the use of Ti electrodes. The procedures have been successfully tested also in particularly complex matrices, such as detergent samples.

An additional study was devoted to effective monitoring of noble metals in solution, which is crucial in order to increase the efficiency of hydrometallurgic processes in mining and the recovery of precious materials from electronic waste. Ti electrodes allow the determination of dissolved Au species in the presence of other metal ions, such as Ag, Fe and Pb. The electrodes exhibit reproducible and repeatable electrochemical responses, even in the presence of high concentration of organic fouling species typical of bio-sorption processes.

In addition, we could ascertain that Au nanostructures grafted on Ti surfaces possess peculiar electrocatalytic properties. Electrodes consisting of similar bimetallic systems are capable to electroxidise glucose in alkaline solutions, but are completely blind to other simple carbohydrates, such as fructose, and to simple alcohols, such as methanol and ethanol. This behavior is significantly different from bulk Au and Au nanoparticles deposited on conventional electrode materials, such as glassy carbon: in alkaline solution these materials are excellent electrocatalysts for any carbohydrates and alcohols. Hence, Ti, as the substrate on which Au nanoparticles are deposited, imparts unusual selectivity to the bimetallic electrode.

Finally, it is possible to envision the exploitation of photoelectrochemical effects, which have been already investigated in the case of bulk and nanostructured TiO2.

9253-43, Session 8

Spectroelectrochemical sensors: new polymer films for improved sensitivity *(Keynote Presentation)*

William R. Heineman, Laura K. Morris, Carl J. Seliskar, Univ. of Cincinnati (United States); Samuel A. Bryan, Pacific Northwest National Lab. (United States)

The selectivity of an optical sensor can be improved by combining optical detection with electrochemical oxidation or reduction of the target analyte to change its spectral properties [1]. The changing signal can distinguish the analyte from interferences with similar spectral properties that would otherwise interfere [2]. The analyte is detected by measuring the intensity of the electrochemically modulated signal. In one form this spectroelectrochemical sensor consists of an optically transparent electrode (OTE) coated with a film that preconcentrates the target analyte. The OTE functions as an optical waveguide for attenuated total reflectance (ATR) spectroscopy, which detects the analyte by absorption. Sensitivity relies in part on a large change in molar absorptivity between the two oxidation states used for electrochemical modulation of the optical signal. Detection limits on the order of 10-5 to 10-8 M have been demonstrated [3,4]. Alternatively, ATR can serve as the excitation light for fluorescence detection, which is generally more sensitive than absorption. Modifying an ITO electrode with an extremely thin (12 nm) Nafion film, enabled a subnanomolar limit of detection to be achieved for the model analyte ruthenium trisbipyridyl, [Ru(bipy)3]2+ . The detection limit was lowered four orders of magnitude by using fluorescence vs. absorbance for the detection of the same analyte [5]. A critical part of the sensor is the ion selective film. It should preconcentrate the analyte and exclude some interferences. At the same time the film must not interfere with the electrochemistry or the optical detection. Therefore, since the debut of the sensor's concept one major focus of our group has been developing appropriate films for different analytes. The three films that we have used most recently are the polymers Nafion [6], a partially sulfonated polystyrene-block-polyethylene-ran-butylene)block-polystyrene (SSEBS) [7], and quaternized poly(vinylpyridine) (QPVP) [8]. Nafion is a unique polymer that consists of two domains: cation-exchange sites and hydrophobic pockets. Thus, it can be potentially used for preconcentration of both cations and neutral molecules. SSEBS has similar properties. QPVP is an anion-exchange film which has demonstrated high stability. The main focus of this talk is the development of poly(4-vinylpyridine-co-styrene) films for use in spectroelectrochemical sensors to enable sensitive detection of target inorganic analytes in complex samples.

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9253-44, Session 8

Trends and challenges for the detection of HME threats *(Keynote Presentation)*

Augustus Way Fountain III, U.S. Army Edgewood Chemical Biological Ctr. (United States)

The recent emphasis on finding technical solutions for the detection of improvised explosive devices (IEDs) has increased the interest in developing bulk and trace chemical sensors as one means to locate these threats. Despite the operational challenges associated with deploying chemical sensors for such applications, the interest in chemical detection continues to be driven by the fact that the explosive charge is the one common element in all IEDs. Homemade explosives (HMEs) pose a unique threat to military and homeland security forces due to the relative ease in both acquiring the materials and constructing the device. Therefore, investment in a means to detect and identify IEDs and their precursor components, especially those hidden inside vehicles or containers, is necessary. Understanding the potential capabilities afforded by exploiting the chemical signatures of explosives first requires understanding their nature and in particular, their quantity, morphology, composition, persistence, transport, and spectral characteristics. All of these factors ultimately impact the development of technology and the concepts of operation or use. The traditional military application of explosives detection towards finding mines has been inadequate to address the current military environment. A concerted effort is still required to develop the capability to detect an explosive threat prior to detonation in a complex, dirty environment; to identify activities associated with IED manufacture; and conduct residue analysis for intelligence or attribution. As part of our scientific development, it has been critical that relevant spectroscopic signatures are accurately collected and validated in order to properly evaluate the performance of existing sensors and for predicting the performance of future, detection capabilities. In order to realize a future capability in standoff explosives detection a full understanding of the spectral signatures remain and must take into account the effects of having a thin film versus having a sparse deposit, the spectral differences between trace quantities and bulk material, as well as the impacts of the substrate impacts on spectral signatures.

9253-45, Session 9

News on electrochemical sensors *(Invited Paper)*

Luca Pini, Metrohm Autolab (Netherlands)

No Abstract Available.

9253-46, Session 9

Rapid, simple and low-cost point of sampling detection of explosives and other analytes of interest *(Invited Paper)*

Adrian Guckian, Ocean Optics, Inc. (Ireland)

Ocean Optics has developed a range of easy to use SERS substrates that provide both sensitivity and selectivity to the measurement. Our gold and silver-based SERS substrates are low cost, can be produced in large volumes and are applicable across a wide range of industries.

The emphasis of our Raman development originally focused on the detection and identification of bulk explosives. More recently, the development of our SERS substrates has enabled us to develop trace level detection of these explosives as well as trace detection of a range of target analytes including narcotics, banned food additives and a range of Raman active taggants. The combination of a miniature Raman device together with a low-cost SERS substrate brings many other opportunities including the possibility of road-side drug detection in samples of saliva.

Surface Enhanced Raman Spectroscopy (SERS) uses gold or silver nanoparticles or structured surfaces to magnify Raman signals and therefore extend the application of Raman spectroscopy to trace level detection. Ocean Optics has developed a range of SERS substrates that provide both sensitivity and selectivity. Our gold and silver-based SERS substrates are low cost, can be produced in large volumes and are applicable across a wide range of industries.

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Our SERS technology provides for complete flexibility in how the substrate is deployed. Typically, our substrates are immobilized on a semi rigid substrate. However, alternative form factors such as dip sticks and swabs have been successfully produced. It is easy to envisage the SERS substrate in the form of an swab that can be used to collect a sample which is then inserted into a handheld analyzer.

An important additional feature of our measurement technique is the possibility to selectively enhance a signal from the target. This can be achieved through the modification of the surface of the nanoparticles by adding functional groups to the surface. This is particularly valuable when measuring complex or heterogenous samples as enhancement can be selectively imparted to target analytes and is particularly useful when used in the life sciences sector.

9253-46

Rapid, simple and low cost point of sampling detection of explosives and other analytes of interest (Invited Paper), Adrian Guckian, Ocean Optics

EMEA (United Kingdom)

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9253-47, Session 9

Optimisation and production of a molecular-imprinted-polymer for the electrochemical determination of triacetone triperoxide (TATP) *(Invited Paper)*

S. K. Mamo, Jose Gonzalez-Rodriguez, Univ. of Lincoln (United Kingdom)

TATP (Triacetone triperoxide, or 1,1,4,4,7,7-hexamethyl-1,4,7-cyclonona-triperoxane) is a peroxide explosive that has become increasingly popular among terrorists and amateur chemists due to its readily available starting materials and a rather simple, although highly dangerous, synthesis procedure which is available on the internet. In recent years improvised explosives devices (IED) that use TATP as explosive component have become more popular among terrorists. In the past decade several terrorist attacks or attempts have been recorded which are directly linked with the use of TATP as the main explosive or as part of IEDs.

Detection of TATP is a challenge as the conventional explosive detection devices and canine detections, commonly used in public terminal controls, depend on the presence of nitro groups and metallic elements which this explosive does not have in its structure. TATP has quite unsuspicious appearance, no significant UV-Vis absorption and no fluorescent properties.

Sensors provide an alternative for fast, selective, sensitive, and portable qualitative and quantitative field analysis of TATP. Biosensors, optical sensors, piezoelectric and electrochemical sensors have been employed for fast and reliable field detection of peroxide explosives.

A molecular Imprinted Polymer to analyse TATP (MIP-TATP) was produced by electro polymerisation using different electrode materials. Cyclic voltammetric anodic current peaks at glassy carbon electrode when compared to platinum, gold, and silver electrodes showed more reproducible signals. Molecularly imprinted polymer modified glassy carbon electrode was prepared by electropolymerization of the functional monomer pyrrole in the presence of the template TATP molecules with LiClO4 as supporting electrolyte using cyclic voltammetry. Electrostatic interaction and hydrogen bonding were responsible for the possible interaction of the template molecules with the pyrrole unit of the polymer which leads to the trapping of the template. The removal of the trapped templates from the polymer matrix was carried out by cyclic voltammetry of the molecularly imprinted polymer modified electrode, in aqueous solution of 0.05 mol L-1 KCl and saline phosphate buffer solution at pH 7.0, in a potential range of -1.0 to +1.4 V (vs. Ag/AgCl) at a scan rate of 0.05 Vs-1 for 3 scan cycles.

A Three-factor two-level factorial design was used to optimize the concentration of functional monomer, concentration of template, and cyclic voltammetric scan cycle using differential pulse voltammetric current peak intensities as response variable.

The molecular imprinted polymer modified glassy carbon electrode demonstrated good performance in low concentrations for a linear range of 0.082 – 4.432 µg mL-1 and a correlation coefficient of r2 = 0.996. The limits of detection (LoD) (based on S/N = 3) and quantification (LoQ) achieved were 0.027 ?g mL-1 and 0.082 ?g mL-1, respectively. The sensor demonstrated very good repeatability with precision values (n=6, expressed as %RSD) of 1.098% and 0.55% for 11.1 and 22.2 µg mL-1, respectively. It also proved selective for TATP in the presence of other explosive substances such as PETN, RDX, HMX, and TNT.

9253-49, Session 10

Preparation and characterization of novel nanosized hybrid materials and their nonlinear optical properties *(Invited Paper)*

Stefanie Dengler, Cordula Hege, Bernd Eberle, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany)

Many laser applications have been developed and established in industry, medicine, research and military during the last years and it is still a growing field. This has multiplied the potential risk of laser-induced damage to human eyes and optical sensor systems. Due to the large variety of laser wavelengths, conventional spectral filters cannot provide a complete protection. Smart and passive solutions with broadband properties are therefore required.

A way is given by devices with optical limiting (OL) properties (decreasing transmittance with increasing fluence) based on nonlinear optical (NLO) effects (nonlinear absorption, nonlinear refraction, induced scattering). These materials were proposed to offer broadband laser protection.

A number of organic and inorganic materials, like dyes, carbon based nanomaterials and inorganic nanoparticles have been found to show a strong nonlinear extinction. However, none of these materials, taken individually, can completely fulfill the requirements like a low threshold, broadband efficiency and a high linear transmittance. An optimization may be achieved by hybrid materials with combined NLO effects.

We fabricated and investigated different hybrid materials suspended in a solvent. They were characterized regarding their linear optical properties by spectral transmission measurements. Their structure was analyzed by electron microscopy and the nonlinear behaviour is discussed regarding their attenuation characteristics.

9253-50, Session 10

Growth and study of nonlinear optical materials for frequency conversion devices with applications in defence and security *(Invited Paper)*

Vladimir Tassev, Michael Snure, Shivashankar R. Vangala, Martin M. Kimani, Rita D. Peterson, Air Force Research Lab. (United States); Peter G. Schunemann, BAE Systems (United States)

With the advance of heat seeking technology providing missiles with sensitivity as high as that of the CCD in a digital camera, the need for compact and broadly tunable IR sources for IR countermeasures is now more urgent than ever. Other possible military and security applications of such sources are laser radar, high speed IR communications, and remote sensing of chemical and biological agents. Some commercial applications are in medicine, environmental sensing, industrial production and spectroscopy. Since existing direct laser sources in these wavebands possess limited wavelengths, lack tunability, and often require cooling to achieve acceptable efficiency, significant research into frequency conversion devices, especially based on quasi-phasematching, has been pursued to provide alternatives. We have studied a series of nonlinear materials including GaAs, GaP, ZnSe and GaN. As a more mature material, OPGaAs was investigated to reveal the reasons for the high optical losses that prevent achieving the expected conversion efficiency. Such are absorption centers around native point defects or impurities and scattering at

antiphase or twin boundaries. It was found, for example, that Si-incorporation is orientation dependent. Thus, Si-adsorption is weaker on (111)B surface than on (001). It turned out that, as we expected, the bonds at the interface between two oppositely orientated areas are predominantly monoatomic (Ga—Ga and As—As). After optimizing the conditions for thick growth of GaP by hydride vapor phase epitaxy on unpatterned substrates, growths were performed on half-patterned templates. They indicated that the fastest growth, 78 μm/h, with vertically propagating domains with a rectangular mesa's shape are on patterns defined on 4° misoriented templates with stripes along [01?]. These results were used as a feedback to the preparation of orientation patterned (OP) GaP templates, which allowed improving OPGaP template quality and scale up the process to 2 and 3 inch wafers. Thick HVPE growths on templates fabricated by two different techniques, wafer fusion and sublattice MBE assisted technique, were performed with growth rates of 50-70 μm/h. The domains were vertical in shape and followed the periodicity of the initial pattern. The maximum thickness for device quality OPGaP achieved to date in a 6-hour long experiment is about 300 μm. To achieve thicker growths requires suppressing the parasitic nucleation around the nozzle where gallium chloride meets phosphine for the first time. This nucleation, which starts to play a major role after the 4th hour of growth, depletes the available precursors, reduces the growth rate and deteriorates the layer quality. Characterization of two and three photon absorption and optical loss are in progress. The challenge with the newer candidates, OPZnSe and OPGaN, was to establish suitable regimes for: (i) hydrothermal growth of OPZnSe on ZnSe or on foreign substrates with small lattice and thermal mismatch and on patterned templates; and (ii) epitaxial growth of (OP)GaN on plain GaN, deposited by MOCVD on sapphire, on half-patterned GaN templates with different orientations and on OP- templates, fabricated by different techniques. Further characterization details will be discussed.

9253-51, Session 10

Improvement of photopysical properties of emissive molecules in DNA matrix *(Invited Paper)*

Norihisa Kobayashi, Wataru Watanabe, Kazuki Nakamura, Chiba Univ. (Japan)

No Abstract Available

9253-52, Session 10

On the versatility of electronic structures in polymethine dyes

Simon Pascal, Alexandre Haefele, Cyrille Monnereau, Ecole Normale Supérieure de Lyon (France); Azzam Charaf-Eddin, Denis Jacquemin, Université de Nantes 2 (France); Boris Le Guennic, Université de Rennes 1 (France); Olivier Maury, Chantal Andraud, Ecole Normale Supérieure de Lyon (France)

Polymethine dyes have always fascinated physicists and chemists since their early use for photography applications in the 1850's and because of their original optical properties, i.e. intense absorption and fluorescence than can be localized in the near-infrared (NIR) region, accompanied by important second and third order nonlinear optic responses.1,2 These characteristics point out polymethines as choice chromophores for applications in modern research fields, such as electro-optic modulation,3 all optical swithching,4 bio-imaging and sensing,5 photovoltaics,6 optical power limiting7,8 or electrochemical fluorescence switching.9

The incorporation of polymethine dyes within devices generally implies its integration in solid matrix such as polymer or sol-gel materials. In the same way, the vectorization of the chromophore in biological media often requires chemical modification for solubilisation, grafting onto particles or targeting of a special analyte. Unexpected loss or enhancement of optical properties have punctually been observed following such modifications of the dye's structure or environment. We propose to use the model developed in Figure 1 in order to rationalize these observations and to define the influence that exogeneous parameters (polarity, pH, counter ion...) can have on the preferential stabilization of one electronic structure of the dye.

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9254-1, Session 1

Progress towards implementation of the QEYSSAT quantum communication satellite *(Keynote Presentation)*

Thomas D. Jennewein, Brendon L. Higgins, Eric Choi, Univ. of Waterloo (Canada)

Ground-based QKD systems are commercially available today. However, these current systems can only cover distances of up to 200 km due to photon absorption in fiber optic cables. Satellite-based quantum communication systems, however offer an approach for surpassing distance limitations even with today's technology, and a truly global network for quantum communication becomes feasible in the near-term. Over the past three years, our group has been working with industry partners to advance a proposed microsatellite mission called QEYSSat (Quantum EncrYption and Science Satellite) through a series of conceptual and technical studies funded primarily by the Canadian Space Agency (CSA). The current platform for the QEYSSat mission proposal is based on a microsatellite, to be located in a low Earth orbit (LEO) at an altitude of approximately 600 km. The payload would have an optical receiver with 40 cm aperture as the main optics. We are currently working on the main technical challenges, which are to advance existing quantum devices to make them suitable for the space environment. The QEYSSat payload will include the capability to analyze and detect single optical photons with high efficiency and accuracy. In order to show the viability of the technical concept, we will present several of our recent theoretical and experimental studies including a comprehensive link performance analysis, QKD experiments over high transmission losses and over a rapidly fluctuating channel.

9254-2, Session 1

Quantum communication to the inside of the International Space Station *(Invited Paper)*

Rupert Ursin, Austrian Academy of Sciences (Austria)

We propose performing quantum optics experiments in a ground-to-space scenario using the International Space Station, which is equipped with a glass viewing window and a photographer's lens mounted on a motorized camera pod. A dedicated small add-on module with single-photon detection, time-tagging and classical communication capabilities would enable us to perform the first-ever quantum optics experiments in space. We present preliminary design concepts for the ground and flight segments and study the feasibility of the intended mission scenario. Such an experimental configuration would enable us to test the limits of quantum mechanics over some hundreds of kilometers and in the presence of an gravitational field gradient. A successful demonstration of these experiments will also provide the basis for a whole variety of additional future experiments (e.g. quantum communication in a down-link or even an inter-satellite link scenario) and will prove the feasibility of global quantum communication using state-of-the-art technology as a kind of path-finder mission.

9254-3, Session 1

Adaptive spatial filtering for daytime satellite quantum key distribution

Mark T Gruneisen, Air Force Research Lab (United States); Brett A Sickmiller, Michael B Flanagan, Leidos (United States); James P Black, Kurt E Stoltenberg, The Boeing Company (United States)

The performance of a satellite quantum key distribution (QKD) system will be highly dependent upon the magnitudes of optical loss and noise in the free-space quantum channel. In daytime, the dominant source of optical noise is the scattering of sunlight by the atmosphere into the quantum channel. Atmospheric turbulence contributes to this problem in that it can limit one's ability to spatially filter this noise. In principle, one can mitigate the effects of turbulence with adaptive optics (AO) technologies. However, the effectiveness of AO in mitigating turbulence will be dependent upon a variety of factors including the atmospheric channel dynamics that are dictated by the satellite trajectory.

We consider the dependence of daytime noise on the receiver field of view (FOV), the role turbulence plays in defining the optimum FOV, and the mitigation of turbulence through tracking and higher-order AO technologies. Simulations of propagation and adaptive compensation quantify the degree to which daytime noise can be reduced and the additional losses that may be incurred as a result of implementing AO technologies. The potential impact on secure key generation rates in QKD protocols will be discussed.

9254-4, Session 2

Room-temperature single photon sources based on nanocrystals in photonic/plasmonic nanostructures *(Invited Paper)*

Svetlana G. Lukishova, Justin Winkler, Univ. of Rochester (United States); Luke J. Bissell, Air Force Research Lab. (United States); Dilyana Mihaylova, Andreas C. Liapis, Univ. of Rochester (United States); Zhimin Shi, Univ. of South Florida (United States); David Goldberg, Vinod M. Menon, Queens College (United States); Robert W. Boyd, Univ. of Rochester (United States) and Univ. of Ottawa (Canada); Guanying Chen, Paras N. Prasad, Univ. at Buffalo (United States)

Room-temperature single-photon sources based on nanocrystal fluorescence in photonic/plasmonic nanostructures:

We present our results towards robust room-temperature single-photon sources (SPSs) based on nanocrystal quantum dots (NQDs), nanodiamonds and nanocrystals with trivalent rare-earth ions (TR3+) in different microcavities. Although currently different color centers in nanodiamonds are most promising single-emitters for room-temperature SPSs, we are also working on development of TR3+ technology, which can be better for SPS applications than using nanodiamonds. The advantages of using TR3+ for SPS applications in comparison with other single emitters lie in their stability against bleaching (long-operational lifetime) and a widely covered spectral range including the optical communication wavelengths. Long fluorescence lifetimes (hundreds of microseconds-milliseconds) of commonly used forbidden transitions of TR3+ are the main restriction for using TR3+ for SPS applications: quantum communication systems need high bit rates, at least several tenths of MHz. For this purpose fluorescence lifetimes should be no longer than ~10 ns. Recently photon antibunching was obtained in TR3+ fluorescence on allowed transitions of single Pr3+ and Ce3+ with ~ 10 ns fluorescence lifetimes offering count rates in free space of up to ~0.1GHz. We are working in the direction to make other forbidden transitions allowed.

As microcavities for single emitters, we used cholesteric

chiral photonic bandgap and Bragg-reflector microcavities. With a future goal of a hybrid photonics/plasmonic SPS, we developed bowtie nanoantennas with polarization selectivity and manipulated nanodiamonds with an AFM tip.

(1) We demonstrated circularly polarized microcavity resonance with definite handedness of CdSeTe NQD fluorescence in glassy (solid) oligomeric chiral cholesteric liquid crystal (CLC) photonic bandgap microcavity. NQD fluorescence antibunching with g(2)(0) = 0.382 was observed in a similar glassy CLC microcavity.

(2) We have also observed circularly polarized fluorescence with definite handedness from Er3+ ions-doped nanocrystals inside a monomeric (E7 and CB15) chiral CLC photonic bandgap microcavity. We used NaYF4 nanocrystals doped with Er3+, Yb3+ and upconverted excitation by 976-nm laser light.

(3) We also investigated a 1-D photonic bandgap microcavity consisting of a layer of colloidal CdSe/ZnS NQDs spin-cast between two distributed-Bragg reflector mirrors. These mirrors, comprised of alternating layers of SiO2 (nSiO2 = 1.54) and SiNx (nSiNx ~ 2.02), were deposited via plasma-enhanced chemical vapor deposition. NQD fluorescence microcavity resonance was observed as well as photon antibunching with g(2)(0) ~ 0.32.

9254-5, Session 2

Chipscale transceivers for quantum communications *(Invited Paper)*

Ryan M. Camacho, Sandia National Labs. (United States)

Future scalable quantum communications technologies will require new tools and devices at the micro-scale that can generate, process, and detect photons for quantum signal processing. While nano- and micro-photonic devices are now routinely used for classical communications processing, significant challenges still remain for accomplishing quantum communication tasks in scalable systems. In this talk, I will give an overview of our team's efforts to overcome some of these bottlenecks and discuss progress towards the construction of a chip-scale quantum transceiver for QKD.

9254-6, Session 2

Advanced single photon sources using cavity-coupled colour centres in diamond *(Invited Paper)*

Jason Smith, Univ. of Oxford (United Kingdom)

After many years of development, robust and user-friendly triggered single photon sources are still elusive, and weak coherent pulses continue to be preferred for practical QKD. The new EC FP7 project Wavelength-tunable Advanced Single Photon Sources (WASPS) brings together six European universities with expertise in diamond colour centres and optical microcavities to build a new generation of triggered sources combining high specifications with room temperature operation. The project aim is to produce devices that can make the transition into non-laboratory environments, providing GHz clock speeds, high efficiencies, and indistinguishable photons. Here I will present the general methodology behind the WASPS project along with some recent results and our latest estimates of achievable device specifications.

9254-7, Session 2

An experimental demonstration of a simple quantum repeater for use with quantum information systems

Ross J. Donaldson, Robert J. Collins, Heriot-Watt Univ. (United Kingdom); Electra Eleftheriadou, Univ. of Strathclyde (United Kingdom); Stephen M. Barnett, Univ. of Glasgow (United Kingdom); John Jeffers, Univ. of Strathclyde (United Kingdom); Gerald S. Buller, Heriot-Watt Univ. (United Kingdom)

Quantum protocols for secure communication (e.g. quantum key distribution or quantum digital signatures) currently operate over relatively short transmission distances when compared to modern classical telecommunication links, which can transport data over inter-continental distances. In classical communication using optical fiber these long transmission distances are primarily due to the use of in-fiber and waveguide optical, allowing the classical signal to be amplified without a significant noise penalty. In order for quantum protocols to be used in long distance secure communication, low noise quantum amplifiers or repeaters are essential. Several interesting theoretical protocols have been proposed for quantum repeaters, including a series of Bell states measurements, but the modest quantum efficiencies of single photon detectors places limitations on practical implementations.

Quantum mechanics appears to prohibit perfect deterministic amplification of an unknown quantum state. Using deterministic amplification on a quantum signal will introduce noise that will overpower any quantum properties of the signal. Nondeterministic protocols working in postselection can be used as a solution to create a low noise quantum amplifier. Several schemes have already been experimentally realized using single-photon sources, or by noise addition and photon subtraction. However, these realizations have the drawback of relatively challenging experimental complexity.

Here we present an experimental realization of a protocol which performs nondeterministic amplification, with high gain and fidelity, on known sets of phase encoded coherent states. The amplification process consists of state comparison followed by photon subtraction. The outcomes of these processes are recorded using thick junction silicon single photon avalanche diodes (Si-SPADs) and time-stamped to permit postselection of successfully amplified states. State comparison and photon subtraction are relatively straightforward techniques which allow our experimental system to operate with equipment that is considerably simpler than required for single photon source based amplification protocols. Our approach uses an attenuated laser diode operating at ?≈850 nm and a clock rate up to 100 MHz as a source of coherent states, allowing for a high rate of amplified data transmission with significantly reduced experimental complexity. This wavelength was chosen to permit compatibility with easily operated commercially available low-noise, high efficiency, peltier cooled Si-SPADs and the approach is applicable to any operating wavelength and detector technology. Using a coherent state source also allows our amplification experiment to be used at mean photon numbers of order one or more, which could be useful for experiments outside of quantum communication where multi-photon pulses are transmitted long distances or through a lossy medium. Our experimental demonstration shows improved fidelity and amplified state production rate over previous experimental systems.

The experimental demonstration simulates a quantum communication system where information is encoded in phase space, using sets of two, four or eight nonorthogonal states. The fidelity and success rate for each set of nonorthogonal phase encodings will be presented for a range of mean photon numbers per pulse.

9254-22, Session 2

Single photon detection and generation with nanowires *(Invited Paper)*

Valery Zwiller, Technische Univ. Delft (Netherlands)

No Abstract Available

9254-8, Session 3

Towards high data-rate quantum cryptography over water *(Invited Paper)*

Bradley G. Christensen, Univ. of Illinois at Urbana-Champaign (United States); Daniel J. Gauthier, Duke Univ. (United States); Alexander D. Hill, Daniel R. Kumor, Kevin T. McCusker, Paul G. Kwiat, Univ. of Illinois at Urbana-Champaign (United States)

It is now well established that the quantum mechanical features of single and entangled photons can be used to enable the only provably secure means of transmitting information over a public channel. Robust, high-rate, free-space optical quantum key distribution (QKD) systems are of interest in a variety of applications where secure data transmission is critical. One such application is for ship-to-ship or ship-to-shore communications. Deploying a QKD system of relevance to such a marine application is extremely challenging because it needs to operate in an extremely variable environment in which turbulence, losses and scattering due to weather and aerosol conditions over the sea deck can change rapidly, leading to transmission that can vary over many orders of magnitude. To contend with such variable conditions, we are investigating novel methodologies, as described here.

To optimize the data rate in QKD systems, we use photon pairs that are entangled in energy and time. The security of the "time-bin" encoding can be monitored by verifying the energy anti-correlations: if an eavesdropper attempts to measure the timing information of a transmitted photon, she will necessarily introduce changes in the frequency spectrum of that photon, which can then be detected by measuring the pair's frequency anti-correlations. While in principle measuring in the conjugate bases will completely secure the shared key between Alice and Bob, the necessary dispersion to secure up to 10 bits of entropy per photon is beyond current technologies. We can circumvent the required dispersion by easing our constraints on an Eavesdropper; that is, we assume Eve does not have any quantum non-demolition (QND) measurement of the photon number. With this assumption, we still maintain advantages over classical cryptography (e.g., Eve cannot retroactively break our code), while also allowing us to encode multiple bits per photons to reach for data rates beyond those of any previously designed systems.

For this experiment, we pump two orthogonal nonlinear crystals to produce polarization entanglement. Two locations on the downconversion cones are collected into independent single-mode fibers. The polarization entanglement is verified by subsequently passing the photons from both channels through a polarization analysis. The two polarization analysis channels share the same optical components (by being spatially separated), but are sent to different detectors. The detector outputs are sent to a time-to-digital converter and each timestamp is recorded. The collected data is then run through low-density parity check code. We have previously seen data rates of 14 MBits/s (after error reconciliation and privacy amplification) for both channels combined, and simultaneously 5.6 bits per coincidence. However, we now have improved detectors with only 25-ns deadtime, allowing us to run at significantly higher rates. Data rates in excess of 25 Mbits/s are expected with these improved detectors.

One of the main challenges associated with transmitting above sea deck is the large amount of loss from Mie scattering. The high losses causes detector dark counts to become significant. To increase the signal-to-noise ratio of our QKD system, we would like to be able to process only pixels which have a high likelihood of detecting the transmitted signal. To do so, we can use a high-intensity beacon beam of a wavelength shifted slightly from the signal beam, transmitted along with the signal, and profiled by a sensitive video camera to determine the corresponding single-photon detector array pixels most likely to contain the signal. Here we will present the initial results of our experimental demonstration of this technique, and discuss its further generalization to an actual marine environment.

9254-9, Session 3

Quantum hyperdense coding

Trent M. Graham, Paul Kwiat, Univ. of Illinois at Urbana-Champaign (United States)

A major goal of quantum information science is to enhance the effectiveness of communication channels. For example, it is possible to use quantum effects to increase the capacity (number of bits Bob can decode per use of the channel) of a communication channel. Using classical state encoding it is only possible for a sender (Alice) to communicate at most a one-bit message for each qubit she sends to a receiver (Bob). However, if Alice and Bob share an entangled pair of qubits, they can double this channel capacity using an entanglement-enhanced communication technique known as super-dense coding [1]. Specifically, if Alice and Bob each possess one qubit of a two-qubit Bell state, then Alice can encode two bits of information on the total quantum state by performing one of four unitary operations on her qubit, transforming the total quantum state into one of four mutually orthogonal two-qubit Bell states. Thus, Alice is able to transmit two bits of information to Bob by sending a single qubit. However, because it is impossible to perform a complete Bell measurement using linear optics in a restricted Hilbert space, Bob can only reliably distinguish at most three of the four possible unitary transformations Alice made. This fundamental limitation lowers the achievable channel capacity of super-dense coding from 2 to 1.59 bits.

If higher dimensional entangled states are used instead of entangled qubit states, then the channel capacity can be further increased. We are constructing an experiment to implement linear hyper-dense (HDC) coding, a technique which can encode up to 2.81 bits per two-qubit photon transmitted from Alice to Bob. By pumping a pair of orthogonally oriented nonlinear crystals with a superposition of two diagonally polarized laser pulses, we create photon pairs that are hyperentangled (simultaneously entangled multiple degrees of freedom) in both polarization and time. One photon from each pair is sent to Alice and Bob. Alice then encodes her message by performing one of seven unitary operations on the polarization and temporal modes of her photon, thus transforming the total state into one of seven hyper-Bell states. Alice then sends the photon to Bob, who uses an embedded Bell-state analysis method [2] to decode Alice's message. Using avalanche photodiodes, it is possible to distinguish six of these seven states, for 2.58 bits per photon. However, with the addition of photon-number resolving photon detectors, it is possible to resolve an additional state, increasing the channel capacity to 2.81 bits per photon, the theoretical maximum for this system [3,4].

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9254-10, Session 3

Efficient quantum key distribution based on pulse-position modulation

Yequn Zhang, Ivan B. Djordjevic, Mark A. Neifeld, The Univ. of Arizona (United States)

Due to the challenge to make perfect single-photon source, weak laser pulses with Poissonian statistics are used instead in practice for quantum key distribution (QKD). In tradition, the considerable amount of zero-photon pulses is abandoned causing the low efficiency of utilizing weak laser pulses. The pulse-position modulation (PPM) has been proposed to improve the key rate of QKD by using both the zero-photon pulses and the real pulses (at least one photon rests inside). This paper first investigates a simple PPM-based QKD protocol

and explores ways in which the key rate can be increased. To be secure, we show that the encoding rule for the proposed PPM-based QKD protocol has to be specifically designed instead of simply encoding bits into pulse positions as that of PPM in classical communications. Notice that to form a valid PPM frame for QKD, the two parties, Alice and Bob, have to agree that exactly one pulse has been sent out and got received per PPM frame duration. The requirement seems to be too tight since the probability of sending out two pulses per PPM frame duration is not negligible. Therefore, we propose the change on the sifting step as follows: Alice after receiving the measurement information (which basis has been selected by Bob and whether a click has happened) smartly rearranges the time slots so that two close pulses are separated and thus used to form two eligible neighboring PPM frames. With the agile sifting strategy, the efficiency of generating valid PPM frames and hence the QKD key rate can be improved. In addition, most QKD applications are facing high loss in the quantum channel, in which most pulses sent out by Alice may not be able to arrive at Bob. Thus, if we insist on the condition of forming an eligible PPM frame as Alice and Bob have to have matched number of pulses sent out and received per PPM frame duration, the yield of eligible PPM frames for QKD will be reduced. To address the high-loss effect, we propose to loosen the requirement by allowing that an eligible PPM frame can also be formed in the following scenario: two and more pulses have been sent out per PPM frame duration (in different time slots) by Alice and at least one pulse has been received by Bob due to the channel loss. We show that the key rate for QKD can be further improved by using this strategy.

9254-11, Session 3

An in-fiber experimental approach to photonic quantum digital signatures that does not require quantum memory

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Classical digital signatures are commonly used in e-mail, electronic financial transactions and other forms of electronic communications to ensure that messages have not been tampered with in transit, and that messages are transferrable. The security of commonly used classical digital signature schemes relies on the computational difficulty of inverting certain mathematical functions. However, at present, there are no such one-way functions which have been proven to be hard to invert. With enough computational resources certain implementations of classical public key cryptosystems can be, and have been, broken with current technology. Quantum digital signature (QDS) schemes, on the other hand, can be made information-theoretically secure based on the laws of quantum mechanics.

Previous experimental demonstrations of quantum digital signatures required long-term quantum memory to operate, rendering their implementation impractical using current technologies. In real usage, there is likely to be a delay between the distribution of signatures, and the time when messages are sent and received. With previous schemes, this would have required recipients to store the quantum signature states (which are sequences of phase-encoded coherent states) for extended periods of time before measuring them. This is impractical, given that current quantum memories are limited to tens of minutes at room temperature. To counter this problem, we have realized a new experimental protocol which does not require quantum memory. This is the first experimental system for the distribution of quantum digital signatures, operating entirely without the requirement of quantum memory. It has been used to carry out a series of experiments with a range of different operating parameters. The new experimental system employs quantum state elimination, a new type of quantum measurement which helps advance the technology of QDS towards real applications.

Our system uses an in-fiber network of interferometers (multiport) to symmetrize the signature states sent from Alice to two recipients, Bob and Charlie. The signature states are sequences of independent phase-encoded coherent states, each sequence containing several coherent states for signing an individual bit. Alice has a choice of clock rate, mean photon number per pulse and signature length, all of which affect the security level of the system and the rate of signature transfer. In our system Alice's coherent states are highly attenuated pulses from a ? ≈ 850 nm laser which are phase-encoded at a clock rate of 100 MHz, then sent through the polarization maintaing single-mode fiber multiport towards Bob's and Charlie's detectors. Bob and Charlie employ quantum state elimination to directly measure the phase of the coherent states, thereby eliminating any requirement for quantum memory.

We will present experimental results recorded with a variety of different operating parameters, along with a discussion of aspects of the system security.

9254-12, Session 3

Quantum-secure authentication of a physical key

Sebastianus A. Goorden, Marcel Horstmann, Allard P. Mosk, Univ. Twente (Netherlands); Boris ?koric, Technische Univ. Eindhoven (Netherlands); Pepijn W. H. Pinkse, Univ. Twente (Netherlands)

Secure authentication is crucial in modern society. Authentication is used to verify whether a person or object has access to a certain place or resource, for instance by checking a password or access card. In communication, parties need authentication to check if they are communicating to whom they intend to.

We experimentally demonstrate Quantum-Secure Authentication (QSA) with a classical key, in which we combine ideas from quantum optics and random light scattering. QSA offers a unique combination of highly desirable properties. It does not rely on unproven mathematical assumptions and there is no requirement whatsoever for distribution and/or storage of secret information. All information about a key can be made public. A consequence of this is that QSA is asymmetric: every person only needs a single key and everyone can authenticate every key. Additional advantages are that the key cannot be copied, that authentication of the key is non-destructive and that authentication of the key is "hands-off". Finally, as we show in our experimental implementation, QSA is straightforward to implement with current technology.

QSA uses a Physical Unclonable Function (PUF) [1] as a key. We choose such a key because they are impossible to copy, even for the manufacturer, due to uncontrollable aspects in the manufacturing process. In our experimental implementation of QSA we use an optical PUF in the form of a strongly multiple-scattering layer of white pigment nanoparticles as a key. Such a key can be used for authentication by illuminating it with laser light. Light that enters the key is multiple-scattered by the randomly organized nanoparticles, causing dramatic random-looking changes to the shape of the light beam. The shape of the returned ("response") light beam depends strongly on the positions of the millions of scatterers in the key as well as on the shape of the incident ("challenge") light beam. Therefore, if the challenge-response behavior of the key has been characterized, it can be used later to authenticate the key by illuminating the key with a challenge light beam and verifying whether the shape of the response light beam is as expected.

Our main contribution is to perform the authentication using light with quantum character, which solves the problem of digital emulation of the physical key. With classical light, an attacker who knows the challenge-response behaviour of the key can measure the challenge and can construct the expected response using alternative means. By using challenges that

contain approximately 1100 spatial degrees of freedom [2] and only approximately 230 photons, quantum-physical principles forbid for the attacker to fully characterize the challenge [3]. Consequently, he cannot know which response to construct. The synergy between quantum optics and an unclonable multiple-scattering key leads to an authentication method with unmatched properties.

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9254-13, Session 4

Enhancement of continuous variable QKD via post-selection *(Invited Paper)*

Timothy C. Ralph, The Univ. of Queensland (Australia)

Quantum key distribution (QKD) generates a common, private random key between two parties using a quantum communications protocol. Such a key can then be used for absolutely secure communications. There are two main flavors of QKD, discrete variable (DV) and continuous variable (CV), which are realized by encoding and then detecting single photons and the quadrature variables of the optical field, respectively. The latter kind has a number of practical advantages. CV protocols that employ post-selection — a classical filtering of the measurement results —enjoy additional advantages in terms of versatility and reconciliation efficiency. However proofs of absolute security for post-selected protocols have until recently been absent.

Here we will describe extending the security analysis of CV-QKD protocols using a family of post-selection schemes to account for arbitrary eavesdropping attacks. We show that the post-selection protocols are equivalent to virtual entanglement-based protocols that include a distillation stage. We introduced a particular 'Gaussian' post-selection and demonstrate how security can be calculated using only experimentally accessible quantities. We explicitly evaluate the performance for the case of a noisy Gaussian channel in the limit of unbounded key length and find improvements over all pre-existing continuous variable protocols in realistic regimes. Finally, we will present experimental results based on an entanglement based CV-QKD system.

9254-14, Session 4

Distributing secret keys using quantum continuous variables *(Invited Paper)*

Eleni Diamanti, Télécom ParisTech (France)

The ability to distribute secret keys with information-theoretic security is undoubtedly one of the most important achievements of the field of quantum information processing and communications [V. Scarani, et al, Rev. Mod. Phys. 81, 1301 (2009)]. The rapid progress in this field has enabled quantum key distribution (QKD) in real-world conditions and commercial devices are now available. Here we are interested in QKD protocols where the key information is encoded on quantum continuous variables, such as the values of quadrature components of coherent states of light. Such continuous-variable QKD (CVQKD) protocols present the major advantage that they only require standard telecommunication technology, and in particular, that they do not use photon counters.

In the last few years, CVQKD protocols have been the subject of important advancements: security proofs against general eavesdropping attacks are available for protocols using Gaussian modulation [A. Leverrier, R. Garcia-Patron, R. Renner, and N. J. Cerf, Phys. Rev. Lett. 110, 030502 (2013)], and field implementations over deployed telecommunication networks have been successfully demonstrated [M. Peev et al, New J. Phys. 11, 075001 (2009), P. Jouguet et al, Opt. Express 20, 14030 (2012)]. However, important issues, namely the limited range of these implementations and the practical security of CVQKD systems, have only recently been addressed. In this work, we present the state-of-the-art in long-distance fiber optic experiments for quantum key distribution with continuous variables and discuss the resistance of CVQKD systems to eavesdropping attacks exploiting auxiliary information channels that are typically not taken into account in security proofs.

We describe a practical implementation of CVQKD over 80 km of optical fibre based on an improved optical setup and newly designed error-correction algorithms required to extract the secret key from the correlated data shared between the two communicating parties, Alice and Bob [P. Jouguet, S. Kunz-Jacques, A. Leverrier, P. Grangier, and E. Diamanti, Nature Photon. 7, 378 (2013)]. Note that previous implementations had been limited to less than 25 km. The employed error-correction codes are suitable for CVQKD protocols using Gaussian modulation of coherent states and homodyne detection, and are available for a wide range of signal-to-noise ratios, which is a crucial element for long-distance operation conditions. Additionally, finite-size effects on the parameter estimation procedure of the QKD protocol were taken into account for the generation of the secret key [P. Jouguet, S. Kunz-Jacques, E. Diamanti, and A. Leverrier, Phys. Rev. A 86, 032309 (2012)], leading to the strongest level of security reported to date for such distances.

Furthermore, we discuss current issues related to security loopholes in practical CVQKD systems due to the existence of side-channel attacks, linked, for instance, to the possible manipulation of the classical phase reference signal that is transmitted through the optical channel [P. Jouguet, S. Kunz-Jacques, and E. Diamanti, Phys. Rev. A 87, 062313 (2013)], or the exploitation of back reflections from optical components to suitably chosen probe signals, which can reveal some part of the secret key. Countermeasures to such attacks are typically easy to implement.

Finally, perspectives for continuous-variable quantum key distribution systems are discussed, ranging from achieving further improved performance of such systems to examining their ability for integration into existing telecommunication networks and, in the long run, to exploiting the standard components employed in CVQKD systems to develop photonic chips for quantum key distribution. This can open the way to the widespread use of this technology for high-security applications within communication networks.

9254-15, Session 4

Towards multimode continuous-variable quantum key distribution

Vladyslav C. Usenko, Laszlo Ruppert, Radim Filip, Palacky Univ. Olomouc (Czech Republic)

Quantum Key Distribution (QKD) is the well-known application of quantum information theory aimed at the development of methods (protocols) allowing the distribution of cryptographic keys between two trusted parties so that the laws of quantum physics provide the security of the keys. It is thus the part of the quantum cryptography, combining quantum key distribution with the secure one-time pad symmetrical cryptosystem, which was proven secure from the formal information-theoretical point of view. The first ideas of QKD were based on the preparation, transfer and measurement of the discrete-variable states such as qubits, being physically implemented as single particles, entangled pairs or faint laser pulses in the typical optical realizations of QKD since photonic states are relatively easy to prepare, transmit and detect. An important milestone was achieved lately when it was shown that coherent states of light are sufficient for QKD over the channels with arbitrarily strong attenuation when the reverse data reconciliation is being used. This indicated the development of the continuous-variable (CV) QKD, which is aimed at increasing the efficiency and applicability of QKD protocols with the use of multi-particle

states (typically squeezed, coherent or entangled states of light in the optical domain). The security of CV QKD protocols was shown using the extremality of Gaussian states in the case of optimal collective Gaussian attacks in the noisy and lossy channels when a Gaussian quadrature modulation and homodyne quadrature detection are being used. However, the effect of multi-mode structure of the signal states was not previously examined. At the same time, multimode states, such as the bright squeezed vacuum states and bright multimode twin-beams, are being actively studied in the past time. Thus, we analyze the security of CV QKD assuming the multimode structure of the signal entangled states and homodyne detection. We study the security of multimode CV QKD in the most general scenario of collective attacks in the noisy channels assuming an eavesdropper is able to hold the purification of the states shared between the trusted parties. We model the multimode homodyne measurement and show the threats to security coming from the multimode structure when the detection is mode-nondiscriminating. Further we study the positive effect of a full or partial knowledge of detection structure by the trusted parties which is able to compensate the information leakage from the multimode channels. We also show the possibility to filter the signal modes at the preparation and detection stages to improve the security of the multimode CV QKD. Moreover, we demonstrate the positive effect of the multimode structure in the pessimistic case of the mode-nondiscriminating detection. Increase of the number of the modes is able to stabilize the key rate in the case when the source modes are fluctuating. We show the stability of the result against the imperfect data processing and the losses and noise in the quantum channel. Our result thus opens the promising pathway towards the implementation of CV QKD with the multimode states of light and even suggests the advantage of using such states.

9254-16, Session 5

Programming nontrivial algorithms in the measurement-based quantum computation model

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We provide a set of prescriptions for implementing a quantum circuit model algorithm as measurement based quantum computing (MBQC) algorithm [1] via a large cluster state. As means of illustration we draw upon our numerical modeling experience to describe (i) a large graph state capable of searching a logical 8 element list (a non-trivial version of Grover's algorithm [2] with feedforward), and (ii) an implementation of blind quantum computation [3]. BQC utilizes the unique separation of the initial entangled state resource from the subsequent single qubit measurements utilized to affect quantum gates, to obfuscate the apparent results performed on the "blind" quantum computer from the true results known to the operator issuing the command sequence of measurement operations. In this work, we have developed several prescriptions based on analytic evaluation of cluster states and graph state equations. These prescriptions can be generalized into any circuit model operations. Such a resulting cluster state will be able to carry out the desired operation with appropriate measurements and feed forward error correction.

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9254-17, Session 5

An approach towards blind quantum computation with continuous variable cluster states

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There is an ever increasing need for information security now and in the future. With the advent of cloud computation there is an obvious need for privacy. Blind computation at the cost of additional overhead allows for a remote server to perform computations on a pre-prepared state without the explicit knowledge of the operations performed or the nature of the original state [1]. Theoretical research for the discrete case has shown the universality of blind quantum computation. Experimental implementations of the discrete case have been demonstrated in cases up to four qubits [2]. With respect to the continuous variable quantum computing paradigm, theoretical work has already begun [3]. For this paper we will build upon the existing theoretical foundations and propose a path towards an experimental realization of blind quantum computation with continuous variable cluster states [4].

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9254-18, Session 5

Device-independent randomness extraction for arbitrarily weak min-entropy

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Expansion and amplification of weak randomness plays a crucial role in many security protocols. Using quantum devices, such procedure is possible even without trusting the devices used, by utilizing correlations between outcomes of parts of the devices. We show here how to extract random bits with an arbitrarily low bias from a single arbitrarily weak min-entropy source in a device independent setting. To do this we use Mermin devices that exhibit super-classical correlations. The number of devices used scales polynomially in the length of the random sequence n. Our protocol is robust, it can tolerate devices that malfunction with a probability dropping polynomially in n at the cost of linear increase of the number of devices used.

Full version of the paper is available at quant-ph > arXiv:1402.0974.

9254-19, Session 5

Misinterpretation of statistical distance in security of quantum key distribution shown by simulation

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This study will test an interpretation in quantum key distribution (QKD) that trace distance between the distributed quantum state and the ideal mixed state is a maximum failure probability of the protocol.

Around 2004, this interpretation was proposed and standardized to satisfy both of the key uniformity in the context of universal composability and operational meaning of the failure probability of the key extraction. However, this proposal has not been verified concretely yet for many years while H. P. Yuen and O. Hirota have thrown doubt on this interpretation since 2009.

In conventional QKD theory, the security level is ensured by the following trace distance [4].

Tr. |? - ?|/2 ≤ ? ...(1)

Here, ? is a distributed quantum state and ? is a uniformly mixed quantum state to be distributed. ? is a security parameter that bounds trace distance. Then, this is called ? secure. In addition, this ? is interpreted as failure probability which correspond to a probability to fail in obtaining an ideal uniformity.

After a quantum measurement, the trace distance is described by following statistical distance

∑k |P(k) – U|/2 ≤ ? ...(2)

? is interpreted as a failure probability in this case, too. This interpretation originates from [5].

However, this interpretation was not concretely tested until today while there were some criticisms on this interpretation [6, 7]. Therefore, this study employed a physical random number generator to simulate statistical distance and the failure probability where the uniform probability distribution was successfully obtained. The result showed this interpretation does not necessarily satisfy the expected situation. Therefore the interpretation is wrong. Other evaluation is necessary to ensure the security of QKD.

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9254-20, Session PS

Preventing side-channel leakage in continuous-variable quantum key distribution

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Continuous-variable Quantum Key Distribution (CV QKD) is the new approach in establishing secure communication based on fundamental properties of quantum mechanics. Security of CV QKD protocols suffers from losses and noise that can be present in communication link as well as at trusted sides. It was shown that preparation noise can already break the security and detection noise confines the key rate, but can help to make protocol more robust against noise in quantum channel. Since equipment used by the sender cannot be perfectly shielded, additional information leakage will unavoidably be present on trusted sender side. By additional information leakage we understand information in classical and in quantum domains (such as timing, power monitoring, electromagnetic, etc.) obtained by an eavesdropper prior to quantum channel for estimation of information encoded into quantum state. We summarize the possible sources of side information, define them altogether as a side channel and further investigate its influence on security. In our considerations, we assume that an eavesdropper cannot control the input of side channel and is only limited to measuring the output.

We consider security of CV QKD protocols that use Gaussian modulation of coherent and squeezed states for information encoding. Initially we investigate the effect of side channel on security against individual attacks with pure losses to define security region. We show that side channel in this case limits the key rate, however it remains positive for any coupling ratio of side channel to the main signal. Further we examine security of QKD protocols with imperfect post-processing algorithms and excess noise present in the channel against more general case of collective attacks. We demonstrate that for collective attacks presence of side channel leads to degradation of the key rate and increases protocols sensitivity to the channel noise.

As a method to compensate the effect of side channel, we suggest noise infusion to the input of side channel in order to reduce the negative influence of additional information leakage. Presumably trusted sender party controls the input of side channel and the value of this additional modulation, therefore latter cannot be influenced or eliminated by an eavesdropper. Equivalent Prepare & Measure and Entanglement-based setups for decoupling of side channel are presented. P&M setup uses supplementary modulator on the input of side channel, while EPR setup involves an additional entanglement source coupled to the main source with the aim of further purification. We show that for any given parameters of the setup additional modulation that effectively decreases the negative impact of side channel in terms of key rate and robustness to excess noise in quantum channel can be found. The positive effect of additional modulation is more pronounced for stronger side-channel losses. We also show that with optimal additional modulation higher secure key rates can be obtained for protocols with imperfect post-processing algorithms comparing to protocols with perfect post-processing algorithm but without optimal input of side channel. Our result describes the promising method of shielding the quantum side channels in continuous-variable quantum key distribution.

9254-21, Session PS

Special properties of single-photon optical fiber sensor for security needs

Marek Zyczkowski, Mieczyslaw Szustakowski, Mateusz Karol, Piotr Markowski, Marta Napierala, Military Univ. of Technology (Poland)

Rules of quantum physics are now fairly well understood and indisputable. On the basis of these principles are built safety systems to guarantee unconditional security of data transmission. This is possible due to the random behavior of the measured photon. Theorems of quantum mechanics are used currently in Quantum Key Distribution systems to determine the encryption key of cryptographic systems. Sending the single photons through the interferometer it is possible to determine the probability distribution of a photon detection at a given output depending on the interferometer inbalance. The use of single photon interference allows reduce the probability of detection of the transmission line protection. Additionally it provides high safety of transmitted information and minor disturbances. The quantum sensor can be a device which allows effectively protect transmission lines. In this paper we demonstrate measurement results of the using single-photon interferometers in security systems and potential capabilities use of such sensors.

9254-30, Session 6

Plasmonic and metamaterial technologies for imaging *(Keynote Presentation)*

David R. Cumming, James Grant, Iain J. H. McCrindle, Univ. of Glasgow (United Kingdom)

Filter and absorber technology is essential for wavelength (e.g. colour) discriminating imaging systems. Whilst this is readily achieved in the visible band using dyed polymers, no equivalent materials exist for longer wavelengths from the NIR up to the terahertz band. In addition to making filters, it is also desirable to make wavelength selective absorbers, for use at longer wavelengths, using bolometric detectors. In this paper we will present new results based on the use of surface plasmon resonance and metamaterial methods that allow us to make hybrid wavelength selective systems, including filters and absorbers, on a single planar structure. Filters operating over the required bands can be made in a single metal film. Using this method we show that wavelengths can be selected pixel-by-pixel across a focal plane, or that a single region can select for more than one wavelength, enabling detectors to be vertically stacked. We also show that absorbers and filters can be interlaced or overlapped, as desired, in a two metal system. As a consequence we are able to demonstrate a very flexible and highly engineerable system of optical control for compact room temperature detectors for multi-spectral imaging and data fusion.

9254-31, Session 6

High operating temperature SWIR HgCdTe APDs for remote sensing

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HgCdTe APDs have opened a new horizon in photon starved applications due to their exceptional performance in terms of high linear gain, low excess noise and high quantum efficiency. Focal plane arrays using HgCdTe APDs have been developed at CEA/Leti and Sofradir and high performance devices are at present available for active and passive imagining. In the present communication, we will focus on recent developments of high operating temperature single element APDs for remote sensing applications in the visible to short wave infra-red (SWIR) range with cut-off wavelengths between 2.7 to 2.9 μm at 300 K. The expected performance of such devices will be discussed in terms of bandwidth and sensitivity as a function of operating temperature, detector diameter and optical coupling. This discussion will be illustrated by the presentation of the performances of two large area thermo-electrically cooled (TEC) detector prototypes with detector diameters in the range of 100 to 200 μm and equivalent input noises ranging between NEP 20-40 fW/√Hz, mainly limited by residual thermal radiation. The first detector has a transimpedance amplifier (TIA) limited bandwidth (20 MHz) and was developed for atmospheric LIDAR measurements (CO2 detection) in collaboration with CNES and LMD. The second detector demonstrator uses a TIA with a bandwidth of 300 MHz and was developed for free-space optical telecommunications and full-wave range detection. Such a prototype has been used to demonstrate error free 80 Mbit/s laser communications from the moon during the lunar laser communication demonstration (LLCD) in collaboration with ESA and NASA.

9254-32, Session 6

Demonstration of an InAsBi photodiode operating in the MWIR

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The Mid Wave Infrared (MWIR) spectral region between 3.0 and 5.0 μm is of great interest for a number of applications including military imaging, gas and biological sensing.Over recent years InAs has attracted renewed interest as it has been demonstrated to operate as an excellent avalanche photodiode with single carrier (electron) multiplication and low excess noise. Furthermore the growth and fabrication has been developed to provide highly uniform wafers with low dark currents. Unfortunately InAs has a cutoff wavelength of 3.5 ?m and is not suitable for various MWIR applications. One approach to extend the cut off wavelength is to make use InAs and InBi to grow dilute-Bismuth containing InAs. InAsBi layers have previously been grown and the photoluminescence results suggested that a bandgap reduction of 55 meV per 1 % of Bi can be obtained. However InAsBi growth requires low temperatures (<400 °C) and near stoichiometric flux ratios, making growth challenging. In this work we report the growth and fabrication that have produced a prosiming InAsBi MWIR photodiode operating at Peltier cooler compatible temperature, which to the best of our knowledge is the first.

The sample was grown on an n+ InAs substrate and comprised a 1000 nm n doped InAs layer (1x1018 cm-3 of Si) grown at 500 °C, followed by a 1000 nm intrinsic region which was formed by ten periods of 90 nm InAs0.98Bi0.02 wells separated by 10 nm InAs barriers to remove Bi from the super-saturated surface and near-surface layers grown at ~350 °C. The sample was then capped with a 1000 nm p+ InAs layer (1x1018 cm-3 of Be) grown at 500 °C . For comparison purposes an InAs pin was also grown with a 1000 nm thick p-i-n layer all grown at 500 °C and with the same doping concentrations as the Bi containing sample. The presence of Bismuth was confirmed via X-ray diffraction analysis. The samples were then fabricated into circular mesa devices and characterized electrically and optically.

Temperature dependent current voltage (IV) measurements show dark current densities of 9.6 x 10-3 Acm-2 and 2.6 Acm-2 at temperatures of 77 and 295 K for our InAsBi diode along with R0A values of 590 and 70 MΩcm2 at 77 and 290 K respectively. An FTIR was used to perform temperature dependent spectral response measurements. As the temperature was increased the cut off wavelength of the InAsBi shifts to longer wavelength, with a maximum cut off wavelength (defined as 50% intensity of the peak wavelength) of 3.95 μm being observed at 225 K. Measurement at higher temperature was not possible due to the increasing dark current from the diode. Compared to the InAs reference this corresponds to a 75 meV reduction on the bandgap. A similar size bandgap shift is observed at all temperatures measured. The temperature dependence of the InAsBi was found to be 0.19 meV/K which is considerably smaller than that of InAs, 0.31 meV/K.

9254-33, Session 6

The Future Dynamic World Model *(Keynote Presentation)*

Thomas J Karr, Defense Advanced Research Projects Agency (United States)

No Abstract Available

9254-34, Session 6

Photonically-enabled Ka-band radar and infrared sensor subscale testbed

Michele B. Lohr, Raymond M. Sova, Kevin B. Funk, Marc B. Airola, Michael L. Dennis, Richard E. Pavek, Jennifer S. Hollenbeck, Sean K. Garrison, Steven J. Conard, David H. Terry, Johns Hopkins Univ. Applied Physics Lab., LLC (United States)

A subscale radio frequency (RF) / infrared (IR) testbed using novel RF-photonics techniques for generating radar waveforms is currently under development at the Johns Hopkins University Applied Physics Laboratory to study target scenarios in a laboratory setting. The linearity of Maxwell's equations allows the use of millimeter wavelengths and scaled down target models to mimic full-scale RF scene effects. Coupled with passive IR/visible sensors, target motions and heating, and a processing and algorithm development environment, this testbed can provide a means to flexibly and cost-effectively generate and analyze multi-modal data for a variety of applications, including verification of digital model hypotheses, investigation of correlated phenomenology, and aiding system capabilities assessment. In this work, concept feasibility is demonstrated for simultaneous RF, IR, and visible sensor measurements of a heated, precessing, conical target. Initial proof-of-principle results are shown of the Ka-band subscale radar, which models S-band for 1/10th scale targets, using stretch processing and Xpatch models.

9254-36, Session 6

Photonics and bioinspiration *(Keynote Presentation)*

Keith L. Lewis, Sciovis Ltd. (United Kingdom)

Biological systems exploiting light have benefitted from thousands of years of genetic evolution and can provide insight to support the development of new approaches for imaging, image processing and communication. For example, biological vision systems can provide significant diversity, yet are able to function with only a minimal degree of neural processing. Examples will be described underlying the process used to support the development of new concepts for photonic systems, ranging from uncooled bolometers and tunable filters for asymmetric free-space optical communication systems, to new cameras capable of simultaneously providing spectral and polarimetric diversity.

9254-37, Session 6

Artificial human vision camera

Jean-François Goudou, Simona Maggio, Michael Fagno, Thales Security Systems S.A.S. (France)

The work presented here is inspired by the human vision system. Our purpose is to inspire from human vision bio-mechanics to improve video analytics objects recognition capabilities.

A first part of the work describes the bio-mechanical discrepancies between human vision and classic cameras and the retinal processing stage that takes place in the eye, before the optic nerve. The second part describes our implementation of these principles.

The eye contains roughly 120M photo-sensors for 180° vision, among them around 7M cones for color vision and objects recognition, mostly in the 60° center of the field of view. The central human vision is very accurate: roughly 500 cones for the central 1 degree field of view, each cone directly linked to an output in the optic nerve. The retina is not only made of photo-sensors. Its structure is complex, and provides first steps of "image processing" before the visual data reach the visual cortex. The retina features three main effects on input images:

• spectral whitening that has 3 important effects: high spatio-temporal frequency signals canceling (noise), mid-frequencies details enhancement and low frequencies luminance energy reduction. This all in one property directly allows visual signals cleaning of classical undesired distortions introduced by image sensors and input luminance range

• local logarithmic luminance compression allowing details to be enhanced even in low light conditions

• decorrelation of the details (center view) and the transient signals (peripheral view)

Basically the center field vision, called foveal vision, leads to the parvo-cellular pathway for red-green color encoding and augmented contours for fixed objects. Moving objects are blurred for the fovea. On the other hand, the peripheral vision leads to the magno-cellular pathway sensitive to change events (motion, transient events, etc.).

We have implemented a similar sensor using three cameras, two cameras for foveal vision and one for broad vision. The two foveal high-resolution cameras have a 2.5x1.4° field of view with HD resolution, thus a 500 pixel per degree resolution, they are mounted on 1 axle turret for simultaneous convergence. A laser telemeter located between the cameras serve as range finder for quick focalization of these two cameras, between 2 and 10m. The third camera has a 60° field of view with lesser resolution, to mimic the peripheral view of human eyes. This whole system is mounted on a 2 axles turret representing the neck. For the retinal model we have reused the "virtual retina" model from Wohrer et al. (2009) and openCV Retina model, based on linear and non-linear filtering of entry images. The result is a first version of a "head" with two "eyes" providing images similar to the signal present in the optic nerve.

This "head" is currently used for video analytics testing, especially saliency map reflex vision and objects recognition algorithms.

9254-38, Session 7

Progress and opportunities in active electro-optical sensing *(Keynote Presentation)*

Gary Kamerman, FastMetrix, Inc. (United States)

No Abstract Available

9254-39, Session 7

Atmospheric energy harvesting: use of Doppler Wind Lidars on UAVs to extend mission endurance and enable quiet operations

Steven Greco, George D. Emmitt, Sidney A. Wood, Simpson Weather Associates, Inc. (United States); Mark Costello, Earthly Dynamics, LLC (United States)

The investigators are developing a hardware/software system that combines pre-mission planning with a numerical model (WRF) and the real-time acquisition of atmospheric data by a small light-weight airborne Doppler Wind Lidar (DWL) aboard a small aircraft or UAS. The set of algorithms called AEORA (Atmospheric Energy Opportunity Ranking Algorithm) reduces mission dependence upon preflight assumptions, extends flight duration and allows for the optimum routing of the aircraft. The envisioned system is one where an onboard DWL is used as "eyes" to detect specific atmospheric energy targets. The lidar detected features are then used with an onboard, weather model driven flight control model to adaptively plan a flight path that optimizes energy harvesting with frequent updates on local changes in the opportunities and atmospheric flow characteristics. We have named this system and set of algorithms AEORA (Atmospheric Energy Opportunity Ranking Algorithm). AEORA will use the WRF model to provide pre-takeoff guidance for routing. After takeoff, the WRF will

be validated by DWL observations, providing a quantifiable measure of confidence in the model for locations out of range of the remote sensors.

An important focus of AEORA has been the development of robust algorithms for energy feature detection from the airborne lidar data. The atmospheric energy features that we have selected are thermals, cloud updrafts, shear zones, obstacle flow, mountain waves, OLEs and wind gusts. Since 2002, over 150 hours of airborne DWL missions have been flown on a Navy Twin Otter aircraft based out of Monterey, CA. The data archives have been searched and numerous days/data sets were selected that included significant atmospheric energy features of interest to AEORA. After initial review of various TODWL data sets and WRF model runs of the same time period, we have identified features in model and DWL data that may be characteristic of the individual energy phenomena mentioned above.

Another core task of AEORA is to rank those opportunities using cost/benefit considerations. The ranking considers the resources (fuel, altitude, electrical power, etc) to be expended getting to the energy target, the mission constraints and the potential energy gain from flying the available features. The target ranking will be continuously updated with new DWL information based upon the distance to target, maximum height(or horizontal speed) gain potential, minimum energy loss and location relative to next likely target. Once an atmospheric feature of interest has been selected, the aircraft flies to the feature and extracts energy entirely autonomously and then awaits updated commands.

Once it has been determined where to fly, flight to target algorithms on board the aircraft will determine the path taken. We have developed flight control laws for four types of atmospheric features 1) lifting air centered about a point (thermals), 2) lifting air organized along a line (ridge lift, mountain waves), 3) wind shear, and 4) random turbulence.

9254-40, Session 7

Active photonic sensor communication cable for field application of optical data and power transmission

Eike Suthau, Ralf Rieske, LUMILOOP (Germany); Thomas Zerna, Technische Univ. Dresden (Germany)

Omitting electrically conducting wires for sensor communication and power supply promises protection for sensor systems and monitored structures against lightning or high voltages, prevention of explosion hazards, and reduction of susceptibility to tampering. While passive photonic sensors can offer a solution for some applications, the ability to power active sensors photonically opens up the full range of electrical sensors. As power demand increases, local energy storage and energy harvesting techniques quickly reach their limits. Power-over-fiber or photonic power is an attractive option for powering remote sensors in the electromagnetically sensitive environments mentioned above, particularly for long-term, maintenance-free applications. It can deliver uninterrupted power sufficient for elaborate sensors, data processing or even actuators alongside continuous high speed data communication for remote sensor application.

Optical technologies have matured through their continuing application in telecommunications. To date photonic power is still rarely utilized due to increased system cost and installation effort. Slow adoption is also partly due to usability issues stemming from laser safety requirements and a lack of robustness in harsh environments, exemplified by narrow connector tolerances and elaborate cleaning procedures. Power-over-fiber niches remain extremely specialized and have resisted both standardization and rationalization. Current systems are typically bulky, sensitive, and expensive, employing conventionally confectioned fiber cables.

This paper proposes an active photonic sensor communication system, which combines the advantages of optical data links in terms of immunity to electromagnetic interference (EMI), high bandwidth, hardiness against tampering or eavesdropping, and low cable weight with the robustness one has come to expect from industrial or military electrical connectors. This is achieved by integrating the electro-optical converters for optical data and power transmission and a permanent fiber-chip-coupling into conventional electrical connectors. Hence, users require no prior knowledge of laser or fiber optics technology and long-term reliability is greatly improved. This paper presents the integrated electronics used to guarantee continuous, reliable data communications while maintaining a highly efficient, adaptive sensor supply scheme. Maximum power efficiency is enabled by an application specific integrated circuit (ASIC) implementing a closed-loop regulation of the sensor power supply and data communications, thus ensuring superior thermal stability under all load conditions. It is demonstrated that the resulting novel photonic sensor communication cable can handle sensors and actuators differing orders of magnitude with respect to power consumption.

Relevant environments include those prone to interference due to electric, magnetic, or radio-frequency (RF) fields, such as, the direct proximity of transmitting antennas or radar systems. Sensors can sustain the high field strengths resulting from nearby stroke of lightning commonly found in exposed aerial masts as well as HPEM (High-Power-Electro-Magnetics) environments found in military scenarios. Superior immunity to eavesdropping and tampering can be a vital advantage for safety and security critical applications, such as tunnel surveillance, low RF access area monitoring, facility and border security.

The miniaturization of the electro-optical converters and driving electronics is as important to the presented development as the energy efficiency of the detached, optically powered sensor node. For this reason, a novel photonic packaging technology based on wafer-level assembly of the high power electro-optical converters on transparent substrates by means of passive alignment will be disclosed in this paper.

9254-41, Session 7

Laser driven X-ray sources for penetrating imaging

David Neely, Rutherford Appleton Lab. (United Kingdom); Robert M. Deas, Defence Science and Technology Lab. (United Kingdom)

When a high power laser is focussed onto a material at intensities of 10^18 -10^20 Wcm-2 it can produce energetic beams of relativestic (upto 10's MeV) electrons which can then be converted into Bremsstrahlung X-ray beams, in a suitable convertor. These X-rays have unique properties in terms of their short (few ps) duration, directionality and small source size which potentially make them suitable as a source for high resolution/penetrating imaging.

In a recent experiment conducted using the high power lasers at the Rutherford Appleton laboratory, the source characteristics in the 50 KeV-5 MeV range have been investigated and optimised. Using a range of targets from low to high Z, the conversion efficiency and spectral emission has been characterised. The target thickness was scanned from a starting point where refluxing effects were present to thickness much greater than the hot electron range and the X-ray scalings observed are compared to simulations. Additional methods to increase the absorbed laser energy were also investigated and the improved conversion efficiency will be discussed. As well as X-ray flux measurements, images from test samples demonstrating the optimum resolution deliverable will be presented.

With the development of higher repetition rate diode driven laser systems, potentially operating at 10's Hz, the requirements and potential for laser driven sources to be used for mine and portal security applications will be presented.

9254-42, Session 7

AlGaInN laser diode technology for defence, security & sensing applications

Stephen P. Najda, TopGaN Ltd. (Poland); Piotr Perlin, Tadek Suski, Lucja Marona, Michal Bockowski, Institute of High Pressure Physics (Poland); Mariusz Leszczynski, Institute of High Pressure Physics (Poland); Przemek Wisniewski, Robert Czernecki, Institute of High Pressure Physics (Poland); Robert Kucharski, Ammono Sp. z o.o. (Poland); Grzegorz Targowski, Institute of High Pressure Physics (Poland); Scott Watson, A. E Kelly, Univ. of Glasgow (United Kingdom)

The latest developments in AlGaInN laser diode technology are reviewed for defence, security and sensing applications such as automotive, manufacturing, communications, remote sensing, health care, oil & gas etc. The AlGaInN material system allows for laser diodes to be fabricated over a very wide range of wavelengths from u.v., ~380nm, to the visible ~530nm, by tuning the indium content of the laser GaInN quantum well. Advantages of using Plasma assisted MBE (PAMBE) compared to more conventional MOCVD epitaxy to grow AlGaInN laser structures are highlighted. Ridge waveguide laser diode structures are fabricated to achieve single mode operation with optical powers of >100mW in the 400-420nm wavelength range with high reliability. Visible light communications at high frequency (up to 2.5 Gbit/s) using a directly modulated 422nm Gallium-nitride (GaN) blue laser diode is reported. An application for GaN blue laser technology is for underwater telecommunication.

High power operation of AlGaInN laser diodes is also reviewed. We demonstrate the operation of a single chip, high power AlGaInN laser diode 'mini-array' consisting of a 3 stripe common p-contact configuration at powers up to 2.5W cw in the 408-412 nm wavelength range. Low defectivity and highly uniform GaN substrates allow arrays and bars of nitride lasers to be fabricated. Laser bars of up to 5mm with 20 emitters have shown optical powers up to 4W cw at ~410nm with a common contact configuration. An alternative package configuration for AlGaInN laser arrays allows for each individual laser to be individually addressable allowing complex free-space and/or fibre optic system integration within a very small form-factor. TopGaN are developing a new range of high power laser array technology over the u.v.- visible spectrum together with new packaging solutions for optical integration.

9254-43, Session 7

Monolithic CMOS-MEMS integration for high-g accelerometers

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Monolithic CMOS-MEMS integration in microsystems is much sought after today as it enables the design and manufacturing of smaller packages at lower overall instrumentation costs [1,2]. In contrast, the conventional modular hybrid approach is still adopted by majority of current MEMS devices through chip-to-chip bonding, wafer-to-wafer bonding, etc as being modular, it reduces the lead and development time when compared to a monolithic approach. But owing to higher packaging costs, large volume manufacturing of modular systems prove to be far more time consuming and expensive as opposed to monolithically integrated systems [1,3,4]. In the case of high-G accelerometers, robustness of the sensor is pivotal to its reliability. Case studies of popular high-G inertial MEMS accelerometers point to interconnect failure as the key source for package level failure when under impact conditions [5]. A monolithic integration scheme greatly increases accelerometer reliability and response characteristics at high-G ranges as it obviates the need for delicate interconnects. This is simply because instead of fragile and rather long wirebonds, a monolithic system would use short vias between the MEMS and the CMOS leading to faster response as well. Furthermore, such an integration leads to better signal-to-noise ratio (SNR) through a reduced interconnect parasitics, lower power consumption and increased sensitivity [1-3].

This abstract highlights work-in-progress towards the conceptualization, simulation, fabrication and initial testing of a silicon-germanium (SiGe) integrated CMOS-MEMS high-G accelerometer for military, munition, fuze and shock measurement applications. Developed on IMEC's SiGe MEMS platform, the MEMS offers a dynamic range of 5 kG and a bandwidth of 12 kHz. The low noise readout circuit adopts a chopper-stabilization technique implementing the CMOS through the TSMC 0.18 ?m process. The device structure employs a fully differential split comb-drive set up with two sets of stators and a rotor all driven separately. Dummy structures acting as protective over-range stops were designed to protect the active components when under impacts well above the designed dynamic range.

IMEC's SiGeMEMS technology is based on a MEMS-last approach. The MEMS is processed on top of the CMOS readout circuits. The standard modules provide a CMOS protection layer, MEMS via and poly-SiGe electrode, an anchor and poly-SiGe structural layer, and thin-film poly-SiGe packaging.

This has proved to be the most promising means of integration as it enables independent optimization of the MEMS and CMOS to an extent. Also, new generations of CMOS can be appended to the structure without impacting the MEMS.

The MEMS was designed and electromechanically simulated using the IMEC design PDK on Coventor clearing all design rules. Tests were conducted to mathematically model the capacitance response using Simulink by inputing several high-G linear dyamic loads while driving each comb set uniquely.

Through differential sensing, excellent linearity was achieved through the split comb-drive. Also, response characteristics such as response and settling time as well as damping conditions were adequately simulated. Finite element analysis was conducted iteratively to observe the structural integrity of the system under harsh out-of-plane dyamic loads. Finally, Input noise characteristics of the ASIC were simulated for good SNR within the operational bandwidth.

Die-level characterization in the form of C-V testing was done to observe the functioning of several device samples under a high voltage sweep simulating to a certain degree the MEMS performance under high-G military grade conditions.

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Digital orthogonal receiver for wideband radar based on compressed sensing

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Digital receiver has been an emerging trend in the design of radar system, which use high-speed ADCs to directly sample the intermediate frequency (IF) or even radio frequency (RF) signal. Some wideband radars, such as ISAR radar, often transmit signal with pretty wide bandwidth to generate enough range resolution. So it is pretty expensive and complicated to sample the IF echo of wideband radar using off-the-shelf ADCs because of the limitation of Shannon-Nyquist sampling theory. Recent theory of Compressed Sensing (CS) indicates that if the information level of the signal is lower than the actual bandwidth, it can be sampled at a sub-Nyquist rate and the information of interest will be reconstructed afterwards.

In recent years, CS has attracted more and more attention in the study of radar signal processing. However, most of those researches focus on the sparsity of radar signal in slow time, not the fast time. So their researches can't solve the problem of sampling signal in digital receiver. There have been a few researches about the sparse representation of radar IF raw data, but their mathematic models are based on the complex echo signal, which is the result of radar receiver and orthogonal down converter.

Complex signal keeps the phase information of signal and is very convenient for signal processing. But in the real world, all physical signals and waveforms are real-valued, and the radar antenna can only transmit and receive real signal, which is the real part of complex signal. As a result, the orthogonal receiver, which converts the real-valued echo to complex signal, is one of the most important parts in the conventional radar system.

When we employ CS to sample the radar IF echo signal, the digital orthogonal demodulator will not be effective for the sub-sampling result. Because the frequency spectrum of the original signal will be destroyed after the sub-Nyquist sampling, and we can't get the corresponding results of orthogonal conversion using conventional orthogonal receiver. In this paper, we focus on designing a feasible system which can implement the compressed sampling of radar IF signal. We try to utilize the CS theory in the designing of digital receiver, and keep the phase information of signal during the reconstruction of original signal from sub-sampled signal.

In the application of CS, the three key challenges are finding sparse representation of signal, designing CS measuring matrix and reconstructing the signal of interest. Following this guide line, we arrange this paper as follows. Firstly, we propose a novel sparse representation of real-valued radar IF echo signal, which is different from most of other researches about CS radar using complex-valued signal. Second, an architecture and hardware design of digital radar receiver based on random sampling is developed. And then, we carry on some experiments based on simulated data to reconstruct the radar echo and range profile of targets from sub-sampled raw data. The results of experiments validate our design and demonstrate the feasibility of our sub-Nyquist sampling and reconstructing algorithm.

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