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Conference
29 October – 1 November 2012

Location
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Kyoto, Japan
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Co-sponsors

Cooperating Organization
Conference 8523: Remote Sensing of the Atmosphere, Clouds, and Precipitation IV
Monday - Wednesday 29–31 October 2012

8523-501, Session PLMon
Space technology for sustainable development
Yasushi Horikawa, Japan Aerospace Exploration Agency (Japan)

Space science and technology and their applications can contribute more efficiently to the efforts of humankind to promote sustainable development in all countries and regions of the world.

Information obtained from space-derived geospatial data is providing essential inputs for decision-making in areas such as disaster management and emergency response. The Earth observation satellites can be well applied through observations of the Earth’s surface from space to help in the preservation of forests by grasping the seriousness of deforestation or with mitigation of devastating disasters by capturing images and studying geographical changes in affected areas. Having “No Sustainable Development without Space” in mind? I would like to speak the significance of the utilization of the Earth observation data. Space technology provides a wide range of essential tools for making informed decisions in support of development at local, national, regional and global levels in both public and private domains.

A continuous monitoring and observation system that feeds into decision support systems and ensures an informed decision-making is crucial. I would also like to touch upon the related activities conducted in the United Nations Committee on the Peaceful Use of outer Space.

8523-502, Session PLMon
Greenhouse gas measurement from space: status of GOSAT Project and recent outcomes
Tatsuya Yokota, National Institute for Environmental Studies (Japan)

Augmenting the surface-based measurements of greenhouse gases such as carbon dioxide (CO2) and methane (CH4) is an important task in better understanding the global carbon cycle. To this end, the Greenhouse gases Observing SATellite (GOSAT) was launched in early 2009. The main sensors onboard GOSAT are the Thermal And Near-infrared Sensor for carbon Observation (TANSO) - Fourier Transform Spectrometer (FTS) and the TANSO - Cloud and Aerosol Imager (CAI). These sensors have been collecting data since June 2009. The column concentrations of CO2 and CH4 are retrieved from the spectral data by TANSO-FTS. The TANSO-CAI data are used to remove scans that are contaminated with clouds. The column concentrations of CO2 and CH4 (TANSO-FTS Level 2 products) have been disseminated to the general public. The quality of the retrieved concentrations was validated by comparing with reference data collected by ground-based FTSs and airborne in-situ instruments. The GOSAT-based CO2 data and ground-based observations were used together to estimate monthly surface CO2 fluxes for 64 sub-continental regions and obtain three-dimensional CO2 distributions. Here, I will present the status and progress of the GOSAT Project and touch on recent major outcomes.

8523-503, Session PLMon
NASA's future Earth science missions: opportunities and challenges
George J. Komar, NASA Goddard Space Flight Ctr. (United States)

The overarching goal of the Earth Science Division at NASA is to advance Earth System science through spaceborne data acquisition, research and analysis, and predictive modeling. This plenary address summarizes recent mission developments and future directions within the NASA Earth Science community.

A central part of this strategy is a robust technology investment program, to improve Earth observation capabilities. After a brief overview of technologies addressing each of these key challenges, the remainder of the talk focuses upon active remote sensing technology developments, including both lidar and radar advancements. The majority of future Earth-science missions will require active remote sensing capabilities. This presentation provides an overview of the technology investments NASA is making in Earth Science.

8523-504, Session PLMon
Introduction of satellite earth observation in China
Xiaochan Liao, The Ministry of Science and Technology (China)

After decades of explorations and technology accumulations, a framework of earth observations has been established in China and among them satellite observation has been playing an important role. This presentation brief summaries 1) the current status of the satellite earth observation systems, data and applications in China, and 2) China’s policy in international earth observation collaborations, including those in Asia-Pacific regions.

There are several satellite earth observation systems in China, including the series of the resource (ZY), the oceanic (HY), the meteorology (FY), and the environmental disaster mitigation (HJ). In addition, the Chang-E (CE-1) and (CE-2) lunar orbiters expanded the satellite remote sensing into deep space. In addition, the second-generation polar orbit meteorological satellite, FY-3, can be used in the fields of global numerical weather prediction, global change, monitoring of large-scale natural disasters and the surface environment. The overall efforts made for satellites data sharing will be described. The application examples in the fields of meteorology, agriculture, environment protection, oceanography, seismology and urban planning, based on China’s satellite data will be presented in this talk.

China plays also actively in GEOSS progress and plays a significant role. The CMACast is one of three GEOSS earth observation data distribution platforms (GEONETCast). It provides the observations over the Asia-Pacific regions from the weather and environmental satellites, such as FY-1D, FY-2C/2D, NOAA-16/17/18, MTSAT-1R, and EOS/MODIS with roughly 22GB data volume per day. China’s activities and policy in international earth observation collaborations, especially in Asia-Pacific regions will be demonstrated. The role of NRSCC in the yearly coordinating of government R & D funds for remote sensing is also introduced.

8523-505, Session PLMon
Remote sensing of Earth and environment for global sustainability
Ghassem Asrar, World Meteorological Organization (Switzerland)

No Abstract Available
8523-1, Session 1

A potential DSD retrieval process for dual-frequency precipitation radar (DPR) on board GPM

Minda Le, V. Chandrasekar, Colorado State Univ. (United States)

Global Precipitation Measurement (GPM) is poised to be the next generation observatory from space that augments the TRMM mission. The GPM mission is centered on the deployment of a core observatory satellite with an active dual-frequency radar DPR, operating at Ku and Ka bands. Two independent observations from DPR provide the possibility to retrieve two independent DSD parameters, namely Do and Nw, at each resolution volume along the height.

Dual-frequency method proposed for the DPR radar can be formulated in integral equations and Do and Nw can be solved at each bin on the assumed microphysical models of hydrometeors. One known error in the dual frequency retrievals is the dual-valued problem when retrieving Do from DPR for rain region. Rose and Chandrasekar (2006), remedied the bi-valued problem by assuming a linear Do as well as Nw model in rain. The algorithm with the linear assumption was tested by Le and Chandrasekar (2009) based on the whole vertical profile including rain, melting and ice through a hybrid method. It combines forward method in frozen and melting region and linear assumption in rain through an iteration procedure along the whole vertical profile. This retrieval algorithm is tested using airborne observations.


8523-2, Session 1

Impact of non-uniform beam filling on spaceborne cloud and precipitation radar retrieval algorithms

Simone Tanelli, Gian Franco Sacco, Stephen L. Durden, Ziad S. Haddad, Jet Propulsion Lab. (United States)

In this presentation we will discuss the performance of classification and retrieval algorithms for spaceborne cloud and precipitation radars such as the Global Precipitation Measurement Mission Dual-frequency Precipitation Radar (GPM/DPR) and notional radars for the Nexrad-In-space (NIS) and Aerosol/Clouds/Ecosystem (ACE) mission concepts. Spaceborne radar measurements are simulated either from Airborne Precipitation Radar (APR-2) observations, or from atmospheric model outputs (e.g., WRF, DHARMa, SAM, RAMS, UWNMS) via instrument simulators contained in the Instrument Simulator Suite for Atmospheric Remote Sensing (ISSARS). Both methods account for the three dimensional nature of the scattering field at resolutions smaller than that of the spaceborne radar under consideration. We will focus on the impact of non-homogeneities of the field of hydrometeors within the beam. We will discuss also the performance of methods to identify and mitigate such conditions, and the resulting improvements in retrieval accuracy. The classification and retrieval algorithms analyzed in this study are those derived from APR-2’s Suite of Processing and Retrieval Algorithms (ASnRAP); here generalized to operate on an arbitrary set of radar configuration parameters to study the expected performance of spaceborne cloud and precipitation radars. The presentation will highlight which findings extend to other algorithm families and which ones do not.

8523-3, Session 1

Development of precipitation retrieval algorithm for passive microwave sounder over land

Satoshi Kida, Takuju Kubota, Misako Kachi, Japan Aerospace Exploration Agency (Japan); Shoichi Shige, Kyoto Univ. (Japan); Riko Oki, Japan Aerospace Exploration Agency (Japan)

Japan Aerospace Exploration Agency (JAXA) has developed and operated near-real-time data processing system with passive microwave radiometer (PMW) data (i.e., TRMM TMI, Aqua AMSR-E, and DMSP SSM/I) and GEO IR data and distributed rainfall products via the Internet (http://haraku.eorc.jaxa/JMSaMP/) as a prototype-type for Japanese Global Precipitation Measurement (GPM) mission products. Core algorithms of the system are based on the combined PMW-IR algorithm developed under the Global Satellite Mapping of Precipitation (GSMaP) project.

The GSMaP algorithm for passive microwave sounders (GSMaP-MWS) has been developed by the window channels (23, 31, 89 and 150 GHz). While the over-ocean GSMaP_MWS algorithm has been developed, currently we’re developing the over-land GSMaP_MWS algorithm. Current rain/no-rain classification (RNC) method over land tends to underestimate rain areas because only scattering-based algorithm is applied over land due to high surface emissivity, leading to missing warm rain. Passive microwave sounders have also the sounder channels; opaque water vapor channels (around 183GHz) and oxygen absorption channels (50-60GHz). The sounder channels are less affected by surface emission. Therefore we develop new RNC method using channels such as 89, 150, 186 and 190 GHz to detect the warm rain which is missed by the current method. In order to estimate the performance of the proposed RNC method, the AMSU-PR matched-up cases are tested. The result shows that the shallow precipitation over land, which is missed by the original RNC method, is detected by the proposed RNC method.

8523-4, Session 1

New GSMaP over-land precipitation retrieval algorithm for AMSR2

Kazumasa Aonashi, Meteorological Research Institute (Japan)

The GSMaP (Global Satellite Mapping of Precipitation Project) over-land algorithm finds surface precipitation rates that give forward-calculated brightness temperature (TB) depressions in higher frequencies best fit with the Microwave Imager (MWI) observation. This algorithm uses TBs around 37 GHz (TB37) and TBs around 85 GHz (TB85). The objective of the present study is to construct the new over-land algorithm for the Advanced Microwave Scanning Radiometer 2 (AMSR2) aboard the Global Change Observation Mission-Water satellite (GCOM-W1), by introducing indices of the frozen precipitation depth and stratiform rain ratio from MWI TBs into the retrieval part.

For this purpose, I introduced the ratio of TB85 depressions to TB37 depressions (R8537) as the index of the frozen precipitation depth. TB85 depressions (Rain85) and TB37 depressions (Rain37) using the conventional GSMaP algorithm. As the index of stratiform rain ratio, I introduced the horizontal precipitation inhomogeneity derived from Rain85 (Sigma85). Then I classified the TMI retrievals with R8537 and Sigma85 and compared them with PR surface rain (Rainsurf) for 1998. Then, I derived linear fitting coefficients between Rain37, Rain85 and Rainsurf for each R8537 and Sigma85 class and precipitation type for 1998. The new retrieval part used these fitting coefficients for the calibration.

I validated the performance of the new over-land algorithm using TRMM data sets for 2003. The results show that the calibration using R8537 and Sigma85 alleviated negative bias of the precipitation retrievals, in particular over Himalaya and South America.

8523-5, Session 1

A development of rain retrieval algorithm from satellite microwave radiometers caused by orography and over high elevations area

Munehisa K. Yamamoto, Aina Taniguchi, Shoichi Shige, Kyoto Univ. (Japan)

Rain retrieval algorithms from satellite-borne microwave radiometers (MWR) utilize lookup tables (LUTs) related between MWR brightness...
temperatures (Tbs) and rain intensity and databases about precipitation characteristics. Since LUT is generated to simulate Tbs from vertical rain profiles through a radiative transfer model, the accuracy of estimation in precipitation amount depends on the input vertical rain profiles. Some previous studies reported that underestimation of precipitation occurred for generated or reinforced rain systems by orography and over high elevation area. In order to improve the underestimation, orographic precipitation identification was applied to the Global Satellite Mapping of Precipitation (GSMaP) algorithm.向上风顶ography and moisture convergence at near the surface calculated by a re-analysis data and a digital elevation map were utilized to identify areas in orographic precipitation, and a new LUT based on a warm rain case was constructed and applied to the GSMaP algorithm. In addition to the case, we examined representative vertical profiles in precipitation for above mentioned precipitation characteristics. Compared to the standard GSMaP product, clear improvement can be found for a orographic precipitation case affected by a typhoon in Taiwan.

8523-6, Session 1
A feasible method for merging datasets of TRMM PR and TMI
Yunfei Fu, Qi Liu, Liang Sun, Yu Wang, Ming Ma, Rui Li, Univ. of Science and Technology of China (China)
The TRMM satellite has operated for more than 14 years and achieved huge measurements through its onboard instruments. The resulting dataset supplies very important information of clouds and precipitation, which improves our knowledge on climate change. However, there are still a few difficulties about the applications of TRMM data. For example, the field-of-views (FOVs) of the TMI measurements range from 37 km 63 km at 10.65GHz to 5 km 7 km at 85GHz while the horizontal resolution of PR is only about 4.5 km. How to merge datasets derived from the two instruments without losing information from the higher-resolution data is a key to help further reveal the detailed microphysical structure of precipitation and clouds. In this study, based upon the fact of overlapping distributions of contiguous TMI pixels (especially at the lower frequencies), the microwave brightness temperature at each TMI channel can be assumed to form a continuous field and simulated by the Approach of Least Square (ALS). According to this principle, precipitation profiles measured by PR and microwave brightness temperatures observed by TMI are merged at the horizontal resolution of PR. Then, the quantitative validation is performed by comparing the mean, variation, and probability density function (PDF) between the original dataset and the merged dataset. The statistical results show that the maximum error is less than 1.5 K and relative error less than 0.9 %, which means the successful of the ALS method to assure fine resolution of the merged dataset.

8523-7, Session 2
TRMM satellite rainfall estimates for landslide early warning in Italy preliminary results
Mauro Rossi, Istituto di Ricerca per la Protezione Idrogeologica, Consiglio Nazionale delle Ricerche (Italy) and Università degli Studi di Perugia (Italy); Dalia Kirschbaum, NASA Goddard Space Flight Ctr. (United States); Silvia Luciani, Alessandro C Mondini, Istituto di Ricerca per la Protezione Idrogeologica, Consiglio Nazionale delle Ricerche (Italy) and Università degli Studi di Perugia (Italy); Fausto Guzzetti, Istituto di Ricerca per la Protezione Idrogeologica, Consiglio Nazionale delle Ricerche (Italy)
Early warning systems predict rainfall-induced landslides comparing rainfall data with landslide rainfall thresholds. These systems are derived using empirical rainfall thresholds defined using rain gauge data. Despite quantitative satellite rainfall estimates are currently available, surprisingly limited researches compare satellite estimates and rain gauge measurements, for the forecasting of possible landslide occurrence. In this work, we validate satellite estimates obtained for Italy by the NASA Tropical Rainfall Measuring Mission (TRMM-RT and TRMM-v6) using rainfall measurements from the Italian rain gauge network (> 1950 rain gauges) for the period 2009-2010. Using cumulative rainfall measurements/estimates for different periods from 3 to 72 hours: (i) we evaluate the correlation between the rain gauge measurements and the satellite estimates in different morphological and climatological conditions, using different models (linear and power law); (ii) we analyze the distributions of the ground-based measurements and the satellite estimates using different statistical approaches; (iii) we compare rainfall events derived automatically from satellite and rain gauge rainfall series, with rainfall events associated to landslides reconstructed using heuristic procedures. Differences are observed among satellite and rain gauge rainfall data for different morphological and climatological areas. Those are larger in mountainous areas, and collectively reveal a complex relationship between the ground-based measurements and the satellite rainfall estimates. Power law correlation model is more appropriate compared to linear. Different statistical distributions characterize satellite and rain gauge data. These results indicate that specific empirical rainfall thresholds have to be defined to fully exploit satellite rainfall estimates in existing early warning system.

8523-9, Session 2
A physically based algorithm for non-blackbody correction of the cloud top temperature for the convective clouds
Chunpeng Wang, Univ. of Michigan (United States); Zhengzhao Luo, The City College of New York (United States); Xianglei Huang, Xiuhong Chen, Univ. of Michigan (United States); Xiiping Zeng, Wei-Kuo Tao, NASA Goddard Space Flight Ctr. (United States)
Cloud top temperature is a key parameter to retrieval in the remote sensing of convective clouds. Passive remote sensing techniques cannot directly measure the temperature at the cloud tops. Here we explore a synergistic way of estimating cloud top temperature by making use of the simultaneous passive and active remote sensing of clouds (in this case, CloudSat and MODIS). Weighting function of the MODIS 11micron band is explicitly calculated by feeding CloudSat retrieval of cloud hydrometeor profiles and temperature and humidity profiles based on ECMWF ERA-interim reanalysis into a radiation transfer model. Among 19699 qualified CloudSat-observed tropical deep convective clouds, the mean emission level is at optical depth ~ 0.91 with a standard deviation of 0.33. Furthermore, the vertical gradient of CloudSat radar reflectivity, an indicator of the fuzziness of convective cloud top, is linearly proportional to the distance between the effective emission level (EEL) of 11micron channel and cloud top height (CTH) determined by the CloudSat (CCTH-EEL) when CTH-EEL>0.6km. When CTH-EEL<0.6km, it shows little sensitivity to the vertical gradient of CloudSat radar reflectivity. Based on these findings, we derive a formula between the fuzziness in the cloud top region, which is measurable by CloudSat, and the difference between the MODIS 11micron brightness temperature and physical cloud top temperature. Similar formula can be derived when we use simulations of the Convective Clouds and Precipitation (CCE) model as a surrogate of the real convective cloud development process. The application of this formula in estimation of cloud-top buoyancy is further discussion.

8523-10, Session 2
Constraining CloudSat-based snowfall profiles using surface observations and C-band ground radar
Ziad S. Haddad, Jet Propulsion Lab. (United States)
The CloudSat Precipitation Radar, launched in 2006, provides vertical profiles of W-band (94 GHz) reflectivity and is sensitive to falling snow through all but the most intense precipitating cloud structures. Precipitation retrievals of falling snow are affected by a wide diversity of factors describing the medium, such as snow particle shape, size, and composition, which in turn are controlled by ambient factors including the environmental temperature and humidity — more factors than can be retrieved with the measurement of the single-frequency radar. Yet satellite-based radometric sounders
such as the Microwave Humidity Sounder (MHS) operate without
the benefit of systematic coincident spaceborne radar observations: radar-derived microphysical descriptions of the falling snow from CloudSat or other radar observations that are serendipitously made
nearly-simultaneously with passive microwave (PMW) radiometer-
only measurements are therefore crucial for passive snow retrieval
methods. At the coarse scale of these PMW observations, the
radiative signal due to the snow is relatively weak compared to the
contributions from the atmosphere and the land surface emissivity.
Using the C-band (5 GHz) polarization-agile King City radar (WKR)
operated by Environment Canada, we examined the vertical
structure of winter precipitation events at coincident overpasses of
CloudSat and NOAA 18 (MHS). Two-dimensional video disdrometer
observations are used to place a mild constraint on the range of
the drop-size distribution parameters that are provided through a
priori databases to dual-frequency (C-W-band) radar retrievals.
Our results show how the Bayesian retrievals using the constrained
database produce water content profiles that more closely replicate
the observed radar reflectivity profiles, transition smoothly between
the single-frequency (CloudSat only) and dual-frequency regions, and
are consistent with the ground and space-borne radars as well as the
radiometer.

Observations using the dual Ka-radar system were performed
in Okinawa Island, in Tsukuba, over the slope of Mt. Fuji, and
in Nagasaki, Japan. In Okinawa Island, the performance of the
measurement has been confirmed by rain observation. In Tsukuba,
one radar was directed in vertical and the other was in slant direction.
By this configuration, total attenuation in the melting layer was
estimated. The objective of the Mt. Fuji experiment was to observe the
melting layer. In Nagasaki, a lot of wet snow fell, and much data on the
snow have been obtained.
The main results are measured k-Ze relationships. For the rain,
reasonable k-Ze relationship has been obtained. The feasibility of
total attenuation in melting layer has been studied. Different k-Ze
relationships have been obtained in snow observations.

8523-12, Session 3
Precipitation observation using a dual Ka-band radar system
Kenji Nakamura, Masanori Nishikawa, Nagoya Univ. (Japan);
Shuji Shimizu, Japan Aerospace Exploration Agency (Japan);
Katsuhiro Nakagawa, Hiroshi Hanado, National Institute
of Information and Communications Technology (Japan)
A dual Ka-band radar system is developed by the Japan Aerospace
Exploration Agency (JAXA) for the GPM DPR algorithm development.
The dual Ka-radar system which consists of two identical Ka-band
radars can measure both the specific attenuation and the equivalent
radar reflectivity at Ka-band. Those parameters are important
particularly for snow measurement. Using the dual Ka-radar system
along with other instruments, such as a polarimetric precipitation
radar, a windprofiler radar, ground-based rain measurement systems,
the uncertainties of the parameters in the DPR algorithm can be
reduced. The verification of improvement of rain retrieval with the DPR
algorithm is also included as an objective.

X-band dual-polarization radars are advantageous to observation
of ice-particle region. In order to clarify characteristics of polarimetric
variables and a microphysical structure in precipitation systems, we
conducted an observation by an X-band dual-polarization radar and
in-situ observation of ice particles by hydrometeor videosondes in
Okinawa during the Baiu period. This study shows vertical profiles of
polarimetric variables, ice particles, and raindrop size distributions in a
stratiform precipitation event observed on 1 June 2011.
The stratiform precipitation was associated with a convective system
near the Baiu front. An echo-top height of 10 dBZ was approximately
9 km above sea level (ASL), and a bright band (BB) was found at
4-4.5 km ASL. In a rain region below the BB, radar reflectivity (ZH)
was greater than 40 dBZ, and the average of differential reflectivity (ZDR)
was 1.5 dB. These values were constant with height. Ground-based
raindrop size distributions showed a high number concentration of
small- and moderate-size raindrops (10^-4 mm^-1 m^-3) in normalized
intercept parameter and 1.4-1.8 mm in median volume diameter). Above the BB (5-6 km ASL), ZDR and specific differential phase (KDP) showed positive values (ZDR = 0.5 dB; KDP = 0.3-0.5° km⁻¹). In that region, a videoseonde imaged column, plate, and capped-column crystals, which sizes were greater than 200 µm. Dendrite crystals and rimed particles were not observed. These results suggest that a large number of column, plate, and capped-column crystals and aggregates of these crystals contributed to the high number concentration of raindrops in the stratiform precipitation.

8523-15, Session 3

Urban flash flood applications of high-resolution rainfall estimation by X-band dual-polarization radar network

V. Chandrasekar, Haonan Chen, Colorado State Univ. (United States); Masayuki Maki, National Research Institute for Earth Science and Disaster Prevention (Japan)

Flooding is one of the most common natural hazards in the world. Monitoring rapidly developing floods in urban regions requires high spatiotemporal resolution measurement of rainfall. This paper deals with a networked radar quantitative rainfall measurement system and its applications for urban flash flood warnings. The US National Science Foundation Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is dedicated to revolutionize our ability to observe, understand, predict and respond to hazardous weather events using a dense network of small, low-power radars that could collaboratively and adaptively sense the lower atmosphere. Quantitative precipitation estimation (QPE) has been one of the important accomplishments since the deployment of CASA in 2005. The dual-pol CASA radars employ the measurement of specific differential phase (Kdp) for QPE process. Being the range derivative of the differential phase shift, Kdp is less susceptible to the path attenuation. The R-Kdp estimator is also immune to the partial beam blockage and hail contamination. The cross-comparison with gauge measurements shows great improvement compared to the current state-of-the-art. The excellent performance of CASA QPE system in Oklahoma test bed encourages the application of this networked radar rainfall measurement method for flooding monitoring in the populous Dallas-Fort Worth (DFW) metropolitan area. The performance of the radar rainfall product in Oklahoma test bed will be summarized in this paper. In addition, the implementation of CASA QPE system in the DFW urban network and its applications for urban flash flood warning is also presented.

8523-16, Session 3

Measurement of vertical air velocity and hydrometeors in stratiform precipitation by the 47-MHz wind profiler radar and 532-nm polarization lidar

Masayuki K. Yamamoto, Kyoto Univ. (Japan); Makoto Abo, Yasukeni Shibata, Tokyo Metropolitan Univ. (Japan); Tomoaki Mega, Hiroyuki Hashiguchi, Noriyuki Nishi, Kyoto Univ. (Japan); Hajime Okamoto, Kaori Sato, Kyushu Univ. (Japan); Toyoshi Shimomai, Shimane Univ. (Japan); Manabu D. Yamanaka, Japan Agency for Marine-Earth Science and Technology (Japan) and SATREPS-MCCOE Promotion Office (Indonesia) and Kobe Univ. (Japan); Mamoru Yamamoto, Kyoto Univ. (Japan); Manik Timbul, Sir Syafrijon, National Institute of Aeronautics and Space (Indonesia)

Simultaneous measurement of vertical air velocity (W), particle fall velocity, and hydrometeor phase was carried out using a 47-MHz wind profiling radar and a 532-nm polarization lidar installed at Sumatra, Indonesia (0.2S, 100.32E, 865 m MSL) in December 2008. The 47-MHz wind profiling radar, referred to as the Equatorial Atmosphere Radar (EAR), measured W and reflectivity-weighted particle fall velocity relative to the air (Vz) simultaneously. The lidar measured linear depolarization ratio (LDR), which is an indicator of hydrometeor sphericity. A stratiform precipitation case on 8 December 2008 and that on 16 December 2008 were compared to describe differences of W, Vz, and LDR. Surface rainfall intensity was greater than 2 mm/h in the 16 December case, while raindrops evaporated until they reached to the ground in the 8 December case. Upward W above the melting level was greater than 0.2 m/s in the 16 December case, while it was weak (less than 0.1 m/s) or absent in the 8 December case. Vz of 1.6 m/s at 300 m above the 0 degC altitude (5.2 km MSL) in the 16 December case was greater than the 8 December case (1.3 m/s). The thickness of melting layer in the 16 December case (300 m) was greater than the 8 December case (300 m). Because Vz is an indicator of particle size, the results suggest that the size growth of hydrometeors under the presence of upward W contributed to the formation of thick melting layer in the 16 December case. Owing to complex interfaces of water-coated ice crystal branches, LDR at the melting level increased 0.17-0.20 in the two cases. LDR of raindrops in the 16 December case (7.0-7.5 m/s) was greater than that in the 8 December case (3.7-3.9 m/s) due to larger sized raindrops in the 16 December case. LDR of raindrops in the 8 December case was less than 0.01, while it was 0.05-0.10 in the 16 December case. A possible reason for the LDR difference is discussed.

8523-17, Session 3

Recent observations of clouds and precipitation by the airborne precipitation radar 2nd generation in support of the GPM and ACE missions

Stephen L. Durden, Simone Tanelli, Eastwood Im, Jet Propulsion Lab. (United States)

The Ku-/Ka-band, Doppler, scanning, polarimetric airborne radar, known as the Airborne Dual-Frequency Precipitation Radar (APR-2) has been collecting data since 2001 in support of many spaceborne instruments and missions aiming at the observation of clouds and precipitation (e.g., TRMM, AMSR-E, GPM, CloudSat, ACE). The APR-2 suite of processing and retrieval algorithms (ASPRA) produces L1 products, microphysical classification and retrievals, and wind intensity estimates. The APR-2 suite of processing and retrieval algorithms (ASPRA) produces L1 products, microphysical classification and retrievals, and wind intensity estimates. ASPRA was also generalized to operate on an arbitrary set of radar configuration parameters to study the expected performance of multi-frequency spaceborne cloud and precipitation radars such as the GPM DPR (Global Precipitation Measurement mission, Dual-Frequency Precipitation Radar) and polarimetric radar for the Aerosol/Clouds/Ecosystem (ACE) mission.

In this presentation we will illustrate the unique datasets collected during the Global Precipitation Measurement Cold-season Precipitation Experiment (GCPEX, US/Canada Jan/Feb 2012) and during the Southeast Asia Composition, Cloud, Climate Coupling Regional Study (SEAC4RS, Thailand/Spurtheast Asia, Aug/Sep 2012). We will focus on the significance of these observations for the development of algorithms for GPM and ACE, with particular attention to classification and retrievals of frozen and mixed phase hydrometeors.

8523-18, Session 4

New cloud science derived from GCOM-C satellite mission

Husi Letu, Takashi Y. Nakajima, Takashi N. Matsu, Tokai Univ. (Japan)

The GCOM-C mission measures essential geophysical parameters on the Earth’s surface and in the atmosphere to facilitate understanding of the Earth system. The GCOM-C mission measures essential geophysical parameters on the Earth’s surface and in the atmosphere to facilitate understanding of the Earth system. Quantitative precipitation estimation (QPE) has been one of the important accomplishments since the deployment of CASA in 2005. The dual-pol CASA radars employ the measurement of specific differential phase (Kdp) for QPE process. Being the range derivative of the differential phase shift, Kdp is less susceptible to the path attenuation. The R-Kdp estimator is also immune to the partial beam blockage and hail contamination. The cross-comparison with gauge measurements shows great improvement compared to the current state-of-the-art. The excellent performance of CASA QPE system in Oklahoma test bed encourages the application of this networked radar rainfall measurement method for flooding monitoring in the populous Dallas-Fort Worth (DFW) metropolitan area. The performance of the radar rainfall product in Oklahoma test bed will be summarized in this paper. In addition, the implementation of CASA QPE system in the DFW urban network and its applications for urban flash flood warning is also presented.
8523-21, Session 4

3D wind field retrieval from spaceborne Doppler radar

Yvon Lemaire, Nicolas Viltard, LATMOS (France)

Numerous space radar missions are presently envisioned to study tropical rain systems. Among them, the BoRita mission, a joint effort between Brazil (INPE/AEB) and France (CNES), could embark a Doppler radar with scanning possibilities onboard a low-orbiting satellite. This instrument could be implemented in addition to a Passive Microwave Radiometer (PMR) between 19 and 183 GHz, an improved ScaraB-like broadband radiometer, a mm/submm PMR and a lightning detection instrument. This package will document the feedback of the ice microphysics on the life cycle or on the heat and radiative budgets. Since the microphysics and the water and energy budgets are strongly driven by the dynamics, the addition of a Doppler radar with scanning possibilities could provide precious information (3D wind and rain fields) and a large statistic of such a critical information over the entire tropics and for all the stages of development of the convection to better understand the tropical convection and to improve the convection parameterization for cloud and climate models and associated direct applications such as now-casting and risk prevention. The presentation will focus on the retrieval methods that can be used to retrieved 3D wind field for various scanning strategies of such a radar. A simulator of the spaceborne radar is developed to estimate the precision on the wind field depending on scanning strategies and instrument parameters and to determine the best sampling parameters.

8523-22, Session 4

Towards next-generation spaceborne precipitation radar systems

Eastwood Im, Simone Tanelli, Stephen L. Durden, Momin Quddus, Jet Propulsion Lab. (United States); Yahya Rahmat-Samii, Univ. of California, Los Angeles (United States)

The Aerosol/Cloud/Ecosystems (ACE) Mission was recommended for a NASA launch in the next decade by the 2007 U.S. National Research Council report “Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond”, hereinafter, “Decadal Survey”. One of the primary goals of ACE is to reduce the uncertainty in the impact of clouds and aerosols on climate modeling. This objective requires that cloud-aerosol interaction be better constrained by simultaneous measurement of clouds and aerosols by radar, lidar, polarimeter, and multi-wavelength imager/spectrometer. The Decadal Survey specifically calls for a cloud radar with 94 and possibly 35 GHz channels for cloud droplet size, glaciation height, and cloud height measurements. Doppler capability and cross-track scanning are also indicated in the same document as highly desirable to achieve the scientific goals.

The “Weather Science and Applications” Chapter of the Decadal Survey also encourages continued development of the technology necessary for the deployment of a TRMM-like radar in geostationary orbit (GEO) to provide the required 15-30 min temporal sampling. Such a system would provide significant improvement over the current capabilities for monitoring hurricanes and other weather systems. NIS (Nexrad In Space) is one such geostationary radar concept initially studied within the NASA Instrument Incubator Program: a Ka-band, dual-beam, Doppler radar with a large (35m) deployable spherical antenna reflector illuminated by mechanically scanning phase array feeds.

As in many families of weather radar concepts the most interesting challenges are defined by the competing scientific requirements for resolution, sensitivity, spatial coverage, repeat time, Doppler and multi-frequency capabilities. The unique geometry of the LEO and GEO radar systems affects all the trade-offs both in straightforward ways and less obvious ones.

In this presentation we will report the latest developments in the advancements towards the definition and implementation of these concepts.

ACKNOWLEDGMENTS: The research described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.
Aerosol-cloud-interaction during contrasting Indian summer monsoon years, 2008 and 2009
Rohini Bhawar, APCC (India)
Contrasting monsoons of 2008 and 2009 provide a test bed to enhance the understanding of the aerosol variability and aerosol-cloud interaction. Vertical aerosol profiles derived from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) are used to delineate the aerosol properties during the 2009 Indian summer monsoon drought. We observed 30-40% increase in the aerosol occurrence frequency (AOF) in lower altitudes (below 6 km) of 2009 while 5-8% enhanced AOF in higher altitudes in 2008. The cloud occurrence frequency (COF) also showed more deep convective clouds in 2008 (13-15%) than in 2009. Cloud Fraction (CF), Aerosol Optical Depth (AOD) and TRMM precipitation data sets have been also used to investigate the aerosol-cloud interaction. We define microphysical effect as the change in cloud fraction with changes in aerosol properties (loading/types) and radiative effect as the changes in cloud fraction in response to the absorption of solar radiation. We observe a faster growth of microphysical effect than the radiative effect in 2009 as compared to 2008. In 2009, we observed presence of atmospheric brown clouds from March to September, which slowed down the microphysical effect and enhanced the radiative effect. This resulted in 30% reduction in the total cloud fraction that might have in-turn reduced precipitation, inducing extreme drought like conditions during 2009.

China Collection 1.1: an aerosol optical depth dataset at 1km resolution over China retrieved from satellite data
Yong Xue, Institute of Remote Sensing Applications (China)
Aerosol optical depth (AOD) measurements (China Collection 1.1) at 1 km resolutions have been derived from the Moderate Resolution Imaging Spectrometer (MODIS) data using the Synergetic Retrieval of Aerosol Properties (SRAP) method over China for the period from August 2002 to now, comprising AODs at 470, 550, and 660 nm. The datasets are validated with sun photometer measurements from AERONET for year 2010. From those 2729 collocations, representing mutually cloud-free conditions, we find that 51% of China Collection 1.1 AOD values comparing with AERONET-observed values within an expected error envelop of 20% and 46% within an expected error envelop of 15%. Compared with MODIS Level 2 aerosol products, China Collection 1.0 AOD datasets have a more complete coverage with fewer data gaps over the study region. From those 2148 collocations which Dark Target or Deep Blue algorithms have values, representing mutually cloud-free conditions, we find that 46% of China Collection 1.1 AOD values comparing with AERONET-observed values within an expected error envelop of 15% and 52% within an expected error envelop of 20%. From 581 collocations which Dark Target and Deep Blue algorithms have no value, representing mutually cloud-free conditions, we find that 45% of China Collection 1.1 AOD values comparing with AERONET-observed values within an expected error envelop of 15% and 48% within an expected error envelop of 20% for Terra and Aqua satellites.
analyses among several satellite data (MOPITT, OMI, and MODIS) and emission inventory (GFE03.1) in Southeast Asia from October 2004 to June 2008 on a monthly basis. As a result, it is suggested that the transboundary air pollution from the biomass burning regions occurred over Southeast Asia, which caused specifically higher air pollutants' concentration at Hanoi, Vietnam in spring dry season.

8523-28, Session 6

Observed radiative effects caused by yellow dust aerosol at Sendai, Japan

Shuichiro Katagiri, Kyohei Yamada, Tadahiro Hayasaka, Tohoku Univ. (Japan); Nobuo Sugimoto, National Institute for Environmental Studies (Japan)

In spring, aerosols mainly consist of yellow dust are sometimes a prevailing around Japan. The radiative effects of yellow sand aerosols have not understood yet sufficiently.

We had the yellow dust event in April 2012 at Sendai, Japan. At our observatory at Tohoku University, we have taken the data from the pyranometer and the pyrogeometer (EKO with Kipp & Zonen), and the lidar system conducted by National Institute for Environmental Studies. The data from lidar system indicates the existence of the yellow dust in very low layer (0-2km). We focus on the time when the yellow dust layer without cloud above is studied to discriminate the radiative effect of yellow dust on the earth.

This observed yellow dust seems to be yielded in Mongolia, by the back trajectory of Hysplit model (NOAA), then blown beyond the mountains between Mongolia and China, and over the sea of Japan, and further into Japan. Yellow dust model indicates that the flow of the yellow dust appeared over Sendai was almost the same lump as the one passed through Niigata lidar observatory located on the 200km west of Sendai.

There are some differences can be seen in the lidar data between Sendai and Niigata. To consider the differences of radiative properties of the dust plume between these sites, we adopt the obtained data into the radiative transfer calculation and compare the estimated radiative fluxes to the fluxes from the pyranometer and the pyrogeometer to distinguish the radiative effects caused by the yellow dust events.

8523-29, Session 6

Ground-based observation of Asia dust aerosol and their impact on climate over northwest China

Jianrong Bi, Jianping Huang, Yuzhi Liu, Lanzhou Univ. (China); Tamio Takamura, Chiba Univ. (Japan); Jinsen Shi, Zhongwei Huang, Jinming Ge, Yongkun Xie, Zhiyuan Hu, Lanzhou Univ. (China); Kahatri Pradeep, Chiba Univ. (Japan)

Arid and semi-arid areas comprise about 30% of the earth surface. Changes in climate and climate variability will likely have a significant impact on these regions. Gobi and desert region over Northwest China is one of major dust aerosol sources in East Asia. To improve our understanding of the impact of dust aerosol on climate, an intensive field experiment has been conducted in Dunhuang (40.49N/94.95E, 8523-29, Session 6)

Retrieving Aerosol Optical Depth (AOD) from satellite remote sensing over bright surface and complex terrain is a challenging problem in climate research. In this paper the aerosol optical depth over Lanzhou area and its vicinity in a 100km * 100km ranges in spring was retrieved by 6S model, without and with the consideration about the Walthall BRDF impact on the retrieved AOD. And then a custom defined aerosol type was selected, with a number spectral distribution of aerosol derived from the observations at the semi-arid climate and environment observatory of Lanzhou University(SACOL,35.57 N, 104.08'E), instead of the default one. The results show that, there are two high value centers of AOD over the Xigu industrial district and the Chengguzun district in Lanzhou, respectively. The significant errors of retrieved AOD over the Lujiaxia reservoir is reduced when the Walthall BRDF model was selected. The comparison between the inversion results and ground-based observations show that the retrieval accuracies of AOD have improved significantly with both BRDF model and the custom defined aerosol model.

8523-30, Session 6

The retrieval of aerosol optical depth with an improved model over Lanzhou and surroundings

Wu Zhang, Jingjing Feng, Xinghua Zhang, Yan Chen, Lanzhou Univ. (China)

Retrieving Aerosol Optical Depth (AOD) from satellite remote sensing over bright surface and complex terrain is a challenging problem in climate research. In this paper the aerosol optical depth over Lanzhou area and its vicinity in a 100km * 100km ranges in spring was retrieved by 6S model, without and with the consideration about the Walthall BRDF impact on the retrieved AOD. And then a custom defined aerosol type was selected, with a number spectral distribution of aerosol derived from the observations at the semi-arid climate and environment observatory of Lanzhou University(SACOL,35.57 N, 104.08'E), instead of the default one. The results show that, there are two high value centers of AOD over the Xigu industrial district and the Chengguzun district in Lanzhou, respectively. The significant errors of retrieved AOD over the Lujiaxia reservoir is reduced when the Walthall BRDF model was selected. The comparison between the inversion results and ground-based observations show that the retrieval accuracies of AOD have improved significantly with both BRDF model and the custom defined aerosol model.

8523-31, Session 6

Aerosol models characterization in arctic region using cluster analysis based on long-term AERONET observations

Chi Li, Ctr. for Earth Observation and Digital Earth (China) and Univ. of Chinese Academy of Sciences (China); Yong Xue, Ctr. for Earth Observation and Digital Earth (China) and London Metropolitan Univ. (United Kingdom); Leik Yang, Beijing Normal Univ. (China); Yingjie Li, Institute of Remote Sensing Applications (China) and Graduate Univ. of Chinese Academy of Sciences (China)

The Arctic region is especially sensitive to climate change. Meanwhile atmospheric aerosol is one of the largest uncertainties geophysical factors in climate modeling, calling for aerosol profiles in Arctic regions with sufficient temporal and spatial coverage. Satellite remote sensing is the best approach to obtain the aerosol information over the Arctic region, for which appropriate aerosol models is required.

In this study, five distinctive aerosol models are classified from level 1.5 Aerosol Robotic Network (AERONET) inversion data using cluster analysis. More than 14,000 cases are collected over 17 AERONET sites in Arctic region from 1995 to 2012. For each case, 23 parameters, including (for four bands) four single scattering albedos (SSA, ?), eight real and imaginary refractive indexes (mr and mi), four asymmetry factors (g), (for fine and coarse mode), two volumetric median radius, two standard deviation of radius and two mode total volumes, and angstrom coefficient (870-440) are input into K-means results and ground-based observations show that the retrieval accuracies of AOD have improved significantly with both BRDF model and the custom defined aerosol model.

8523-32, Session 6

Scattering properties of the heterogeneous and non-spherical haze particles in the SWIR band

Meng Fan, Institute of Remote Sensing Applications (China)
and Graduate Univ. of Chinese Academy of Sciences (China); Liangfu Chen, Shenshen Li, Jinhua Tao, Lin Su, Mingmin Zou, Dong Han, Ying Zhang, Institute of Remote Sensing Applications (China)

Recently, the haze days occur frequently in China, especially, in rapidly developing parts of eastern China. However, the multiple scattering due to the high aerosol concentrations in haze events may lead an overestimation for CO2 retrieval in the shortwave infrared (SWIR) wavelength range (~1.6μm) using satellite data. For effectively estimating the influence of the multiple scattering caused by haze particles on the misestimating for CO2 retrieval, it is necessary to well understand the scattering properties of the haze particles in the SWIR band. Several transmission electron microscopy observations have indicated that most of the particles in haze samples are heterogeneous and non-spherical, and are always covered by visible coatings. In this paper, for 1.6μm, the effect of complex component on the scattering properties of both single non-spherical particles and aggregates are investigated using numerically effective medium theory and core-mantle theory. For the single non-spherical particles, the scattering parameters (e.g. scattering phase function, single scattering albedo, extinction coefficient and absorption coefficient) were calculated by combining T-matrix method and the Maxwell-Garnett effective medium theory. And for the aggregates, the diffusion limited aggregation algorithm was used for generating aggregates with different numbers, morphological structures and sizes of spherical monomers, and then the core-mantle Generalized Multi-particle Mie (CMGMM) method was used to compute the scattering parameters. Results from calculations indicate that the differences of backscattering among different types of aerosols are even larger than those of forward scattering. And the relative humidity (RH) could lead to large changes of the scattering properties.

8523-34, Session 7
Vertical structures of IWC from CloudSat retrievals and NICAM simulations
Byung-Ju Sohn, Seoul National Univ. (Korea, Republic of); Seung Hee Ham, NASA Langley Research Ctr. (United States)

Profiles of ice water content (IWC) were examined using CloudSat Level 2B Radar-Visible Optical Depth Cloud Water Content (2B-CWC-RVOD) data, and derived results were used for validating those from Nonhydrostatic ICosahedral Atmospheric Model (NICAM) simulations. Cloud layers above 253-K level are only used as ice clouds in this study, whose altitudes are higher than 9 km over the tropics whereas near surface over the polar regions. For the chosen clouds, each ice water content (IWC) profile was normalized by its cloud-layer mean value. And then the cloud-level height was normalized by its cloud depth in such way to have normalized vertical axis (z*) between 0 and 1 for cloud base and top, respectively, i.e. z*=(z-zb)/(zt-zb). The maximum peak in CloudSat IWC profile is appeared at z* < 0.5, implying that hydrometeors are mainly concentrated in the middle and lower part of the cloud layer rather than the higher part. It is also shown that the geometrically thicker cloud has a maximum IWC at lower z*, probably because of larger ice particles falling within the deep convective cloud. On the other hand, the general shape of IWC profiles seems to be not much varied with latitude or season. Comparison of NICAM simulations with CloudSat IWC profile results shows that NICAM is comparable to CloudSat. But the maximum IWC appears to be stronger for the NICAM.

8523-35, Session 7
Modeling of tropospheric integrated water vapor content using GPS, radiosonde, radiometer, rain gauge and surface meteorological data in a tropical region (French Polynesia)
Jonathan Serafini, Jean-Pierre Barriot, Lydie Sichoix, Univ. de la Polynésie Française (French Polynesia); Abdelali Fadli, Otago Univ. (New Zealand)

The integrated precipitable water (IPW) in the troposphere can be subject to strong spatial and temporal variations, especially over tropical regions. The IPW is estimated from three different data sources collected at or nearby the University of French Polynesia site. For this purpose, eight years (2001-2008) of GPS data from the IGS station THTI are processed with respect to the precise point positioning (PPP) mode of the GIPSY-OASIS II software package. We compare the IPW from the permanent GPS data with that measured, over the same period, from radiometer and radiosonde observations which were carried out at Faa’a Airport located near the GPS station. Then the IPW is estimated using two known tropospheric models, the Saastamoinen model and the Global Forecast System (GFS) model of one degree latitude by one degree longitude grid spacing. The IPW from Saastamoinen model is computed using the corresponding surface meteorological data (pressure, temperature and relative humidity). As such models are not well adapted to the Polynesian micro-climate, we conduct a correlation analysis between these models and the ones derived from the mentioned techniques. Finally, in order to better model the IPW, these models are combined and readjusted using rainfall gauge and surface meteorological data.
This simulation system has been proven to be an important tool within NESDIS for satellite processing system development. The simulated data products have been used in AQUA, METOP and NPP satellite data processing system development. The simulation system provides the ‘real’ time observations from the following instruments: Atmospheric Infrared Sounder (AIRS), Infrared Atmospheric Sounding Interferometer (IASI), Cross track Infrared Sounder (CrIS), Advanced Microwave Sounding Unit (AMSU-A), the Humidity Sounder for Brazil (HSB), the Microwave Humidity Sounder (MHS) and the Advanced Technology Microwave Sounder (ATMS).

The utility of this system is: (1) Provide the downstream customer the ‘real’ observation that supports algorithm development and testing; (2) to provide a robust data distribution environment for development and testing of the satellite processing system to allow for a smooth transition of the satellite data processing system from development to operations, during both the integration and test phases of the system transition.

This simulation system is not limited to the pre-launch satellite observation processing development, but can also be used to monitor and validate the on orbit observations and to analyze the abnormal instrument measurements. In this paper, the design of the simulation system and the applied algorithms are presented in detail. The existing limitations and possible future improvements are also discussed.

8523-39, Session 8
On the cloud observations in JAXA’s next coming satellite missions (Invited Paper)
Takashi Y. Nakajima, Takashi M Nagao, Husi Letu, Tokai Univ. (Japan); Haruma Ishida, Yamaguchi Univ. (Japan); Kentaroh Suzuki, Jet Propulsion Laboratory, California Institute of Technology (United States)

The use of JAXA’s next coming satellites, the EarthCARE and the GCOM-C, for observing overall cloud systems on the Earth is suggested. These satellites will be launched in the middle of 2010-era and contribute for observing aerosols and clouds. Since clouds exert an important influence on the planet’s water and energy balances and processes, more observations with understanding of their lifecycle are required. The CloudSat and the CALIPSCO present a new epoch in cloud observation with the purpose of revealing the particle transition from CCN to rain droplets via cloud and drizzle particles. For instance, the CFODD, a new visualization method of the CloudSat radar reflectivities show transition of cloud growth, from cloud droplet mode to rain mode via drizzle mode very clearly. The EarthCARE is a solution for observing aerosols, clouds, and radiation, using cloud radar, lidar, multispectral imager, and broadband radiometer. Doppler capability in the cloud radar investigates vertical motion of cloud particles. On the other hand, the GCOM-C/SGLI is a comprehensive imager that has 19 spectral bands from UV to thermal infrared. Advantages of the SGLI are, wide swath that contributes global-scale observation, two polarization bands for detecting aerosols over land area, and long-term monitoring continued from past satellite missions. It is expected that the coupled use of these sensors reveal details of aerosol and cloud evolution process. In this paper, we’d like to introduce recent progresses of aerosol and cloud observations from satellites, and mention about future research plan.

8523-40, Session 8
Simulation for spaceborne cloud profiling Doppler radar: EarthCARE/CPR
Hiroaki Horie, Nobuhiro Takahashi, Yuichi Ohno, Kenji Satoh, National Institute of Information and Communications Technology (Japan)

The EarthCARE is the joint mission between Europe and Japan. There are 4 sensors on the EarthCARE satellite and one of key sensor of them is Cloud Profiling Radar (CPR). In order to obtain enough sensitivity for cloud, which is ~40 DBZ after 10 km integration, the CPR uses W-band frequency. In order to measure the vertical velocity of cloud and rain, the CPR has Doppler measurement capability, so EarthCARE/CPR is the W-band first Doppler radar from space to observe cloud and precipitation.

Because the effect of satellite velocity and beam width makes spread Doppler spectrum, the measurement error of Doppler velocity is significantly large. So Doppler simulation becomes difficult, which is taken into account. There are some proposed simulation methods, and we also proposed the simulation method to calculate summation from each distributed target for hit by hit. The result is quite satisfied, but it takes much time for the calculation. One reason of this is to calculate 2-dimensional integration, which is coded by MATLAB. So in order to shorten calculation time, we modified integration method and use lower level language such as C. Then the calculation time is much improved. In addition, we developed simple simulation method. The expected values for Z-factor and Doppler velocity are calculated at first, then predicted measuring accuracy is added.

8523-41, Session 8
Advances in cloud screening and retrieving algorithm for the multispectral imager onboard the EarthCARE satellite
Takashi N. Matsui, Takashi Y. Nakajima, Tokai Univ. (Japan); Haruma Ishida, Yamaguchi Univ. (Japan); Kentaroh Suzuki, Jet Propulsion Lab. (United States); Hajime Okamoto, Yuichiro Hagihara, Kyushu Univ. (Japan)

The cloud screening and retrieving algorithms for the Multi-Spectral Imager (MSI) on-board the EarthCARE satellite have been developed. Some difficulties, however, remain in use of the cloud mask and retrieved properties obtained from passive instruments such as the MSI, MODIS, and GCOM-C/SGLI: contamination of cirrus and/or sub-pixel clouds in “clear pixel”, difficulty of cloud screening for pixels over snow/ice surface or at nighttime, and interpretation of cloud droplet effective radii retrieved using different SWIR bands. It is interesting to note that the EarthCARE has two active instruments in addition to the MSI: Cloud Profiling Radar (CPR) and the Backscatter Lidar (ATLID), which have advantages of vertical observations of clouds and aerosols. Thus, we consider that the advantage of the active instruments will provide keys to solutions of the above-mentioned difficulties in the passive remote sensing. The high accurate cloud detecting by the active instruments can be used for evaluation and characterization of the cloud-screening algorithm for the MSI. The visualization of cloud vertical structure by the active instruments can be used for interpretation of the cloud droplet effective radii from the MSI. In addition, the synergistic use of the MSI and the active sensors with help of the cloud model interpretations will give more understanding of cloud process with vertical/horizontal inhomogeneous distribution. These advances in the MSI cloud algorithms will contribute to the cloud algorithms for other passive instruments. In this paper, we introduce the advances in cloud screening and retrieving algorithms for the EarthCARE/MSI.

8523-78, Session 8
The EarthCARE Cloud Profiling Radar, its latest design and testing results from the engineering model
Hirotaka Nakatsuka, Toshiyoshi Kimura, Yoshihiro Seki, Gaku Kadosaki, Yoshiya lide, Kazuyuki Okada, Japan Aerospace Exploration Agency (Japan); Nobuhiro Takahashi, Yuichi Ohno, Hiroaki Horie, Kenji Satoh, National Institute of Information and Communications Technology (Japan)

No Abstract Available
8523-42, Session 9

Statistical analysis of the subtropical cloud regime transition in the northeastern Pacific Ocean: observations from AIRS and MODIS compared to ERA-40 and other sounding instruments

Mathias Schreier, Univ. of California, Los Angeles (United States) and Jet Propulsion Lab. (United States); Brian H. Kahn, Kay Suselj, Qing Yue, Jet Propulsion Lab. (United States)

We present a synergistic approach that utilizes satellite observations to investigate the subtropical cloud regime transition in the northeastern Pacific Ocean. Hyper-spectral infrared radiances, cloud parameters, and atmospheric thermodynamic profile retrievals obtained from the Atmospheric Infrared Sounder (AIRS) and the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to create representative statistical moments. The analysis is done for the transition of clouds from stratuscumulus near the California coast extending to trade cumulus towards the southwest. We analyze differences in the statistical behavior of cloud parameters, lower tropospheric stability, and variations in temperature (T) and water vapor (q) profiles, and demonstrate the differences and similarities among the different cloud types. The statistics are compared to European Center for Medium Range Weather Forecasting 40 Year Re-analysis (ERA-40) data and additional satellite observations from microwave instruments in the same region for the same cloud types. Additionally, the satellite and reanalysis datasets are used to simulate ensembles of AIRS radiances that are compared to the observed radiances and are sorted by cloud type. This type of a statistical comparison of simulated and observed AIRS radiances provides additional important constraints that are useful for the assessment of satellite retrievals and evaluating atmospheric variability in climate models.

8523-44, Session 9

Categorizing precipitating clouds by using radar and geostationary satellite

Parichat Wetchayont, Tadahiro Hayasaka, Syuichiro Katagiri, Tohoku Univ. (Japan); Takehiko Satomura, Kyoto University (Japan) and Climate Physics Lab., Div. Earth and Planetary Sci. (Japan)

Cloud information such as cloud cover, cloud type and cloud system is very important in study of atmospheric radiation and precipitation. Many methods for classification of cloud type have been developed. However, validation using observational data is not sufficient enough, mainly because of difficulty in direct observation of nonrainy clouds such as cirrus. This research aims at categorizing rain cloud related to rain rate and brightness temperature, considering a remote area or ungauged basin that lack of rainfall measurement. We use the radar and geostationary satellite to categorize those of rain cloud variety. Split-window data measured by Japanese Geostationary Multifunctional Transport satellite (MTSAT) are used for cloud type categorization. Principle of this method is based on a threshold technique, which uses infrared brightness temperature TB at 10.9 µm (T11) data, and its difference from TB at 11.9 µm (T11-12) in two-dimensional histogram. By empirically adjusting thresholds in the two-dimensional histogram, six cloud types are categorized over Phimai radar station in Thailand. For cloud top height (CTH) it is estimated by matching to the atmospheric vertical temperature profile of reanalysis data, then compare with CTH from radar. The comparison shows reasonable agreement of CTH in case of single cloud type is observed, while bigger differences were obtained for cloud at different levels presented. Relationship between cloud type category results and rain rate derived from gauge and radar shows dominant relation of Cumulonimbus with high intensity rain rate. These results will contribute to rainfall estimation by radar in future work.

8523-45, Session 9

Cloud optical depth measured with ground-based, uncooled infrared imagers

Joseph A. Shaw, Paul W. Nugent, Brian J. Redman, Montana State Univ. (United States); Sabino Piazzolla, Jet Propulsion Lab. (United States)

Recent advances in uncooled, low-cost, long-wave infrared imagers provide excellent opportunities for remotely deployed ground-based remote sensing systems. However, the use of these imagers in demanding atmospheric sensing applications requires that careful attention be paid to characterizing and calibrating the system. We have developed and are using several versions of the ground-based “Infrared Cloud Imager (ICI)” instrument to measure spatial and temporal statistics of clouds and cloud optical depth or attenuation for both climate research and Earth-space optical communications path characterization. In this paper we summarize the ICI instruments and calibration methodology, then show ICI-derived cloud optical depths that are validated using a dual-polarization cloud lidar system for thin clouds (optical depth of 3 or less).

8523-46, Session 9

Retrieval of cirrus cloud radiative properties from brightness temperatures in infrared window bands

Hironobu Iwabuchi, Soichiro Yamada, Tohoku Univ. (Japan)

The present understanding of cirrus microphysical property climatology is limited, which is an important key for better understanding the earth radiation budget and climate. An algorithm using three bands of MODIS (bands 29, 31 and 32) in the infrared window region has been developed for retrieval of cirrus radiative and microphysical properties. We have developed a semi-analytical formula of the brightness temperature, which represents the dependence of the infrared signal on atmospheric and surface parameters. The accuracy of the approximation is about 0.34 K in band 29 and 0.18 K in bands 31 and 32, with significant correlations between the errors in each band. The solution for the inverse problem is from an optimal estimation based on the maximum a posteriori, whereby a prior information such as observation noise and modeling error are taken into account. As known in previous studies, the infrared method is sensitive to the effective surface temperature and cloud top temperature, which should be given with high accuracy. Sensitivity tests for the brightness temperature and retrieval error analysis showed that compared to the two-band split-window method, the three-band retrieval is capable of reducing the retrieval errors in optical thickness (τ) for optically thin cirrus (τ < 1) and in effective particle radius (Reff) for very small particle sizes (Reff < 5 µm). In general cases, the three-band retrieval is better to stably obtain the cirrus cloud properties with higher accuracy.

8523-62, Session 9

Cloud liquid water retrieval using AMSR-E on land

Dabin Ji, Jiancheng Shi, Institute of Remote Sensing Applications (China)

This article presents a new method to retrieve cloud liquid water (CLW) on land using passive microwave radiometer AMSR-E. The method is based on a formula of the brightness temperature at frequency 18.7GHz and 36.5GHz (τTb18.7)/τTb36.5 is used to retrieve CLW, due to its sensitivity to CLW and its non-sensitivity to other component of the atmosphere. In the retrieval, the surface emissivity parameter - ratio of surface emissivity polarization difference of 18.7GHz and 36.5GHz - is used as the auxiliary data. The surface emissivity parameter in clear sky is firstly retrieved using AMSR-E brightness temperature data and MODIS water vapor product, and then the surface emissivity parameter in cloudy condition is estimated using 7-days combination of it in clear sky. The surface temperature is retrieved using AMSR-E vertical brightness temperature at frequency 36.5GHz according to a regression equation. And the cloud top height is estimated using...
MODIS cloud product combined with SRTM-DEM data. A look up table technology is used in the retrieval to improve computational efficiency. The look up table contains five fields: surface temperature, the surface emissivity parameter, cloud top height, CLW and Tb18.7/Tb36.5. When surface temperature, surface emissivity parameter, cloud top height and Tb18.7/Tb36.5 are provided, the CLW can be retrieved according to the look up table. Finally, the CLW obtained from Atmospheric Radiation Measurement is used to validate the retrieved CLW, and the precision is 0.139mm.

8523-47, Session PSWed

**Influence and discrimination of clouds in the detection of dust and sandstorms using AVI**
Yoshinobu Kato, Fukui Univ. of Technology (Japan)

The AVI method can detect the dust and sandstorms (DSS) in satellite images both at daytime and night. The aerosol vapor index (AVI) is defined as AVI=T12-T11, where T12 and T11 are the brightness temperatures at 12µm and 11µm wavelength, respectively. The fault of AVI method is to mistake thick clouds for DSS occasionally. Iino et al. (2004) proposed the composite color image (R:G:B=AVI:band6-band1:T11) with the representation of MODIS bands) for discriminating DSS from clouds in daytime images. In this paper, Terra/Aqua-MODIS data are used. First, it is explained that usual clouds bring the effect of AVI<0, and the clouds with very large optical thickness and very large grain size may bring the effect of AVI=0, by using the BTD vs. T11 charts of Inoue (2006) where the BTD=AVI. Examples of the cloud images of AVI>0 are shown and interpreted using the AVI vs. T11 scatter chart. Next, the views of objects (DSS, usual ice-cloud, usual water-cloud, ice-cloud with large optical thickness, water-cloud with large optical thickness, snow field and ice, land, sea) in the single-band images (bands 1, 3, 4, 6, 7 and 8.6) and Tb18.7/Tb36.5, Tb12/Tb32) and the band-difference images (bands 1-band3, band4-band3, band6-band1, band7-band1, T12-T8.5) are examined. The good composite color images which can discriminate DSS from clouds etc. are (R:G:B=AVI:band6-band1:T11) and (R:G:B=AVI:band4-band3:T11) in daytime images, and (R:G:B=T11:AVI:none) in night images.

8523-48, Session PSWed

**Algorithm development for remote sensing of aerosol from MSI**
Satoru Fukuda, Japan Aerospace Exploration Agency (Japan); Teruyuki Nakajima, Hideaki Takenaka, The Univ. of Tokyo (Japan)

The EarthCARE is intended to observe cloud and aerosol 3 dimensionally, and to provide more detailed information to refine the prediction of climate change. EarthCARE will equip 4 instruments, Cloud Profiling Radar (CPR), Atmospheric LiDar (ATLD), Multi-Spectral Imager (MSI), and BroadBand Radiometer (BBR). In these four instruments, CPR and ATLD, which are active sensors, are intended to obtain vertical structure of the atmosphere. On the other hand, MSI is a passive sensor, and intended to obtain horizontal structure of the atmosphere. MSI’s Aerosol product is composed of aerosol optical thickness over ocean, aerosol optical thickness over land, and Angstrom Exponent over ocean. Over the ocean, 680nm and 860nm are used to retrieve aerosol optical thickness and Angstrom Exponent by use of 2-channel method (Higurashi and Nakajima, 1999). Over the land, we need to estimate ground reflectance to retrieve aerosol optical thickness. Generally speaking, a reflectance of land is higher than that of sea, and has more temporal and spatial variance. Currently, we are planning to compare 3 methods to obtain ground reflectance. The first one is to use climatological value. The second one is to make MSI’s original albedo product by choosing minimum reflectance data of MSI. But, the swath of MSI is as narrow as 150km. It is difficult to gather enough radiance data to make ground reflectance. The third one is to extrapolate ground reflectance on larger wavelength to the ground reflectance on visible wavelength. We will compare and discuss these methods.

8523-49, Session PSWed

**Multi-angular polarized remote sensing of aerosol over East Asia**
Tianhai Cheng, Xingfa Gu, Donghiae Xie, Hao Chen, Institute of Remote Sensing Applications (China)

The impact of aerosol on climate is considered as one of the main uncertainties. Even though the significance of aerosol in climate change is well recognized, there exist large uncertainties. One of the greatest challenges in studying aerosol impacts on climate is the immense diversity, which make the impact of aerosol on climate change must be quantified on a regional rather than just a global-average basis. Satellite observations are only possible method to provide systematic observations.

Despite this multitude of approaches, the AOD retrieval from satellite data is still not satisfactory. The accuracy of remote sensing aerosol characterization is limited by the difficulty to model the local optical properties of aerosol. Multi-angle polarized measurements provide an alternative approach for the study the aerosol particles.

In this paper, the aerosol properties over East Asia are studied using multi-angular total and polarized remote sensing. The microphysical and optical properties of aerosol are studied based on the AERONET sun-photometer observations over East Asia, and the vector radiative transfer model coupling the BRDF model and BPDF model of surface reflectance was used to study the TOA reflectance and polarized reflectance of aerosol. The sensitivity of reflectance and polarized reflectance to aerosol microphysical optical parameters are evaluated. Based on the studies of the sensitivity, the basic theory of using the remote sensing data of multi-angular polarized to retrieve the aerosol properties over East Asia is proposed. Analysis and validation of the results are presented using AERONET observations, AOD products of POLDER and MODIS.

8523-50, Session PSWed

**Evaluation of aerosol single scattering albedo derived from ozone monitoring instrument and its applications over East Asia**
Qi Liu, Yulan Hong, Yunfei Fu, Univ. of Science and Technology of China (China)

Single Scattering Albedo (SSA), quantifying the radiative absorption capability, is an important optical property of aerosols. Ground-based means have been extensively exploited to acquire aerosol SSA, but there were no satellite-based SSA measurements until the advent of advanced remote sensing techniques, such as the Ozone Monitoring Instrument (OMI). Although the overall accuracy of OMI SSA is estimated to approach 0.1, its regional availability is unclear. Four-year SSA daily measurements from three Aerosol Robotic Network (AERONET) sites in China (Xianghe, Taihu, and Hong Kong) are chosen specially to clarify the accuracy of OMI SSA in the specific locations. Results show that on a global scale the OMI SSA is systematically higher and has poor correlation with AERONET observations. In the Xianghe, Taihu, and Hong Kong site, the correlation coefficients are 0.16, 0.47, and 0.44, respectively, suggesting distinct qualities of OMI SSA and the worst in Hong Kong, which is probably caused by different environments. The two SSA data yield the best agreement in Taihu site, with the precision is 0.139mm. The impact of aerosol on climate is considered as one of the main uncertainties. Even though the significance of aerosol in climate change is well recognized, there exist large uncertainties. One of the greatest challenges in studying aerosol impacts on climate is the immense diversity, which make the impact of aerosol on climate change must be quantified on a regional rather than just a global-average basis. Satellite observations are only possible method to provide systematic observations.

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**8523-51, Session PSWed**

**Satellite aerosol retrieval using dark target algorithm by coupling BRDF effect over AERONET site**

Leikyu Yang, Beijing Normal Univ. (China) and State Key Lab. of Remote Sensing Science (China) and Henan Polytechnic Univ. (China); Yong Xue, Institute of Remote Sensing Applications (China) and London Metropolitan Univ. (United Kingdom); Jie Guang, Institute of Remote Sensing Applications (China); Chi Li, Ctr. for Earht Observation and Dibal Earth (China) and Graduate Univ. of Chinese Academy of Sciences (China); Yingjie Li, Institute of Remote Sensing Applications (China) and Graduate Univ. of Chinese Academy of Sciences (China)

In most satellite aerosol retrieval algorithms even for multi-angle instrument, the simple forward model based on Lambertian surface assumption is assumed to simulate top of the atmosphere (TOA) spectral reflectance, which does not fully consider the surface bi-directional reflectance functions (BRDF) effect. The approximating forward model violates the radiative transfer model, reduces the size of the look-up tables, and creates faster algorithm which is important in the operational processing. At the same time, it creates systematic biases in the aerosol optical depth (AOD) retrieval.

AOD product from the Moderate Resolution Imaging Spectroradiometer (MODIS) data based on dark target algorithm is considered as one of accurate satellite aerosol product at present. Though it performs well over a global scale, uncertainties are still found on regional in a lot of studies. The Lambertian forward model employed in the retrieving algorithm may be one of the uncertain factors. In this study, we first use radiative transfer (RT) simulations over dark target to assess the uncertainty to what extent is introduced from the Lambertian surface assumption. The result shows that the error in AOD retrieval could reach 0.2. Then the Lambertian forward model and the BRDF forward model are respectively employed in AOD retrieving from MODIS data over several AERONET sites using GSV/RT code. In the BRDF forward model, the directional reflectance is conventionally estimated from spectral-ratios for the dark target, while the BRDF properties are extracted from MCD43A1 product. The validation shows that accuracy in AOD retrieval has been obviously improved by employing the forward model accounting for the BRDF effect.

**8523-53, Session PSWed**

**HCl/Cly ratios of just before the breakup of the Antarctic vortex as observed by SMILES/MLS/ACE-FTS**

Takafumi Sugita, National Institute for Environmental Studies (Japan); Yasuko J. Kasai, National Institution of Information and Communication Technology (Japan); Yukio Terao, National Institute for Environmental Studies (Japan); Sachiko Hayashida, Nara Women’s Univ. (Japan)

The International Space Station (ISS) / Japanese Exposure Module (JEM) borne instrument, the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES), was successfully launched by the Japanese H-II Transfer Vehicle (HTV) on 11 September 2009 to measure chemical species in the stratosphere. We focus on inorganic chlorine species measured inside the late spring Antarctic vortex, when hydrogen chloride (HCl) was a main component of the total inorganic chlorine (Cly). On 19-24 November 2009, SMILES measured southern latitudes up to 66 degrees South. High HCl/ Cly ratios up to 0.9 were observed at altitude of 18 km (near 460 K potential temperature level). This characteristic agrees well with that observed in the past spring inside the Antarctic vortex. Comparisons with other satellite instruments, Microwave Limb Sounder (MLS) and Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS), were also made, and the results have shown the validity of the SMILES HCl data quantitatively. We also examined the validity of such a feature in the recent past by using the MLS data between 2004 and 2011. It is found that this feature is rather regular in this late spring period in the Antarctic. Implication for this is to suggest that the future trend of Cly in the stratosphere can be deduced at this time and location by utilizing some aircraft or balloon measurements of HCl even below 20 km, as if no satellite measurement of HCl in the upper stratosphere in the future.

**8523-54, Session PSWed**

**DRAGON-Osaka experiment with local pollutants and long-range transported Asian aerosols**

Makiko Nakata, Sonoyo Mukai, Itaru Sano, Yuzuru Nakaguchi, Kinki Univ. (Japan); Brent N. Holben, NASA Goddard Space Flight Ctr. (United States); Nobuo Sugimoto, National Institute for Environmental Studies (Japan)

It is known that local spatially and temporally resolved measurements of atmospheric aerosols in Asian urban city are meaningful since the aerosol distribution in East-Asia is complicated due to the increasing emissions of anthropogenic aerosols and natural dust significantly varies with the seasons. Osaka, Kobe, Kyoto, and Nara are famous ancient cities in Japan. Thus, they are located in very close each others (all cities are included in around 7070 km2 area). Therefore, air quality in the region is slightly bad compared to remote area due to industries and auto mobiles. In recent years, Asian dusts and anthropogenic small particles some times transported from China and cover those cities throughout year. And hence a project NASA/Drasgon-Asia is planned here in March of 2012.

In this work, we intend to show the spatial and temporal variation of atmospheric aerosols in East Asia, especially around AERONET/Osaka site and Dragon-Asia project, named “DRAGON-Osaka”. AERONET Osaka site was established in 2002 in the campus of Kinki University. Nowadays, LIDAR, PM2.5 / 10 measurements and others are available. The site data are used for algorithm development of aerosol retrieval over busy city because the site is located in unvegetated area. However, human activities in this region also emit the huge amount of pollutants, thus it is needed to investigate the local distribution of aerosols in this region. In March 2012, to obtain maximum efficiency of DRAGON-Osaka, several Cimels are deployed at more sites as soon as possible.

**8523-55, Session PSWed**

**DRAGON-West Japan campaign in 2012: regional aerosol measurements over Osaka**

Itaru Sano, Sonoyo Mukai, Kinki Univ. (Japan); Brent N. Holben, NASA Goddard Space Flight Ctr. (United States)

It is known that the aerosol distribution in Asia is complicated due to the increasing emissions of anthropogenic aerosols in association with economic growth and natural dust significantly varies with the seasons. Therefore it is clear that local spatially and temporally resolved measurements of atmospheric aerosols in Asian urban city are necessary. Since Osaka, Kobe, Kyoto, and Nara are located in very close each others (all cities are included in around 7070 km2 area), they are called KANSAI or West-Japan all together. The population of the region is around 13 millions including neighbor prefectures, accordingly air quality in this region is slightly bad compared to remote area. Furthermore, in recent years, Asian dusts and anthropogenic small particles some times transported from China and cover these cities throughout year. DRAGON (Distributed Regional Aerosol Gridded Observation Network) is a project of dense sun/sky radiometer network in the urban area. The DRAGON-West Japan field campaign was performed over Osaka and neighbor cities with 8 AERONET instruments from March to end of May in 2012. In this work, initial measurements of DRAGON Osaka filed campaign are described.

**8523-56, Session PSWed**

**Geographical and climatological characterization of aerosol optical depth distribution of MODIS in China**

Yuxiang Luo, Xiaobo Zheng, Institute of Plateau Meteorology, CMA (China) and Guizhou Institute of Mountainous Climate
and Environment (China); Tianliang Zhao, Environment Canada (Canada) and Key Lab of Atmospheric Physics and Environment, CMA (China) and Nanjing University of Information Science & Technology (China); Hong Luo, Yunnan University (China)
The Ahui-Tengchong Line or the internationally known “Hu Line” divides China into the east and west parts, based on differences in China’s population, geography, climate and economy, all of which are closely associated with the aerosols over China. By using the aerosol optical depth (AOD) data of MODIS during years 2000-2010, the geographical and climatological distributions of aerosols over China are presented, and the ‘Hu Line’ is found also to describe a geographic division of aerosols over China; on the east part, the monthly AOD varies from the peak (/>0.5) during March and June to the low of around 0.3 in November and December with an annual mean of about 0.45, mostly contributed by anthropogenic aerosols from the human activities; on the west part, the AOD is dominated by the naturally emitted aerosols with an annual mean of 0.25 changing between the high (about 0.3) in the period of April to July and the low (<0.2) from October to January. The positive and negative trends in annual AOD over 2000-2010 are respectively found in the regions on the east and west. Asian monsoon has a notable impact on the interannual variability of aerosols over the east region by modulating the atmospheric transport and precipitation. The interannual aerosol variations in the west are strongly influenced by dust emission sources in the deserts. The dust weather processes control the natural dust emissions. The maximal AOD of 0.3 in the region of the west China could be brought by the frequent dust storm events.

8523-57, Session PSWed
Microphysical properties of low clouds over the North Pacific Ocean
Takumi Maruyama, Tadahiro Hayasaka, Tohoku Univ. (Japan)
It is well known that low clouds are widespread over the North Pacific Ocean during summer. Previous ship observations suggested that low clouds (stratus and fog) are likely to occur when sea surface temperature (SST) is lower than surface air temperature (SAT). Although there are relative many studies about the relationship between meteorological field and cloud fraction, there are few studies regarding cloud microphysical properties. Therefore the mechanism of cloud occurrence, maintenance and disappearance is not well understood.
In this study, for the first step of understanding the cloud mechanism, we investigated the SST-SAT relationship and microphysical properties of low clouds by using MODIS satellite observations and MERRA reanalysis data. We divided the North Pacific into four regions according to meteorological condition and made basic statistical analysis about cloud properties in each region. The statistical analysis indicates that in the region where SST-SAT value is the lowest, cloud effective particle radius is larger and cloud droplet number concentration is smaller than those in the other regions. Then we divided cloud area into two parts according to positive or negative value of SST-SAT and carried out statistical analysis. Examination of the relationship between SST-SAT and cloud microphysical properties indicates that in the negative SST-SAT area, the effective particle radius is larger and the droplet number concentration is smaller than the positive SST-SAT area. These results suggest that SST-SAT relationship can be one of important factors determining cloud microphysical properties in the summer North Pacific region.

8523-58, Session PSWed
Cloud characteristics in global arid and semi-arid regions detected by A-train satellite measurements
Xiaodong Ding, Lanzhou Univ. (China); Yuhong Yi, Science Systems and Applications, Inc. (United States); Jianping Huang, Jiming Li, Zhongwei Huang, Lanzhou Univ. (China)
Arid and semi-arid regions are strongly influenced by the global climate change. Previous studies have shown that these regions have significant increasing variability from the aspects of human activities and nature climate variability. Clouds constitute a crucial climate regulator and a sustainable water resource for arid and semi-arid region which covers one third of continent area with about 1 billion people. Understanding cloud physical characteristics and vertical structure in these regions is very important and meaningful. The collocated CALIPSO, CloudSat, MODIS data are used to study the cloud characteristics and their vertical structures in global arid and semi-arid regions. The two year collocated are analyzed. The prevalent clouds in arid and semi-arid area are first identified. The seasonal and spatial variation of cloud top height are studied. Cloud water paths from CloudSat. Calipso and MODIS datasets are also compared here. The results show that cloud top height has obviously seasonal and spatial variation ranging from 6 km to 10 km. In winter, most of the clouds are cirrus and altostratus, the mean cloud top height is about 8 km and decreases to 7 km with increasing lower cloud fraction in summer. It was found that generally good agreement exists between the cloud liquid water path from CloudSat and MODIS. However, wide spatial and temporal distributions exist. This study will lead a better understanding of cloud distribution over the arid and semi-arid regions.

8523-59, Session PSWed
A new method for retrieving the vertical distribution of extinction coefficient of stratocumulus clouds from collocated active and passive satellite data
Jiming Li, Jianping Huang, Xiaodong Ding, Lanzhou Univ. (China)
Stratocumulus clouds would severely affect earth energy balance and climate change. It is very hard to obtain the vertical distribution of microphysical properties of stratocumulus clouds due to the limitation of observational techniques in the past. Examining the profiles of liquid water content in actual stratiform boundary layer clouds, it is found that the droplet number concentration within stratiform clouds exhibits an approximately constant value. Therefore, a novel method to retrieve the vertical distribution of extinction coefficient of stratocumulus cloud is developed by using of collocated active, passive satellite data and an adiabatic cloud model. The vertical profile of attenuated backscatter signal for water clouds by the transient response function of space-based lidar (CALIOP) is first corrected. Then, the effect of any transient responses of CALIOP on the attenuated backscatter profile of the water cloud is removed. Last, the profiles of extinction coefficient of water cloud was retrieved from iterative process in the lidar equation by combined the adiabatic cloud model, cloud optical depth from MODIS, and validated attenuated backscatter profile from CALIOP. This novel method will also be evaluated and compared with the extinction results from the ground-based lidar.

8523-60, Session PSWed
Relationship between cloud base height retrieved from lidar and downward longwave irradiance
Kyohi Yamada, Tadahiro Hayasaka, Tohoku Univ. (Japan); Nobuo Sugimoto, National Institute for Environmental Studies (Japan)
Downward longwave radiation is a key process to understand the climate change, energy budget, and water cycle at the earth’s surface. Cloud is a dominant factor to determine the intensity of longwave radiation. It is widely known that cloud cover, base height, and cloud thickness have strong effects to downward longwave radiation, however there are not so many studies on the quantitative evaluation of relationship between cloud properties and downward longwave radiation.
The intent of study is to quantify the impact of cloud property on the downward longwave irradiance (DLI) under overcast condition. In this study, we used the data obtained with OGR-4 pyrgeometer at Tsukuba, for the period from April 01, 2006 to March 31, 2009. We analyzed that the principles which determine cloud emissivity are cloud base height, cloud base temperature, and cloud thickness. Cloud base height and base temperature are detected by Lidar and radiosonde observation, respectively. Cloud optical thickness is
estimated from cloud top height obtained by MTSAT. It is found that the cloud base height and corresponding temperature are almost proportional to DLI. However, the effect of cloud thickness is limited to DLI because thick cloud performs as black body object for longwave radiation. In case of large amount of water vapor, the impact of cloud base height and temperature on DLI becomes small. Water vapor has the wide absorption bands for longwave radiation, and thus contribution of cloud to DLI becomes relatively small.

8523-63, Session PSWed
A novel calibration method of the spaceborne precipitation radar using surface NRCS
Runfeng Yang, Beijing Research Institute of Telemetry (China); Cheng Li, Memorial Univ. of Newfoundland (Canada); Lianghai Li, Yong Yu, Beijing Research Institute of Telemetry (China); Hua Liang, Beijing Institute of Space Machinery (China)

In this paper, we perform statistical analysis on the surface Normalized Radar Cross Section (NRCS) measured by the Tropical Rainfall Measurement Mission (TRMM) satellite in 2011. Our analysis results manifest that although the NRCS data (for sea and land) appears to be random and has a large standard deviation, the per-orbital or daily average value is relatively stable. Therefore, we propose an innovation method to calibrate system parameters of the Spaceborne Precipitation Radar (SPR) and estimate the stability of SPR performance using the per-orbital or daily average value of surface NRCS as the reference. We conduct theoretical analysis and simulations to verify the calibration accuracy of the proposed method based on the TRMM observation data (data set 2A21). Our results demonstrate that using the proposed method, we can not only achieve a better than 0.17dB calibration error (1sigma) of the antenna relative gain at different scan angles and a better than 0.11dB calibration error (1 sigma) of the system gain, but also reduce the system gain calibration period to 1.5 hours given that the satellite orbital altitude is 400km. The proposed calibration method is not constrained by the time and space conditions and does not require the SPR operate in a special calibration mode. Therefore, it provides an effective method to ensure high calibration precision, as well as to monitor SPR status and estimate the SPR performance stability over time.

8523-65, Session PSWed
Satellite observation of water vapor over East Asia during summer monsoon season
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The water vapor during summer monsoon season play a dominant role in precipitation and hydrological cycle over East Asia. Satellite sensors such as MODIS and AIRS provide a good spatial coverage of the highly variable constituent. Column water vapor (CWV) from different satellite sensors and AERONET sites were compared and analyzed in eastern China. This study provides an overview of variations in water vapor during the summer monsoon period, as well as potential impact factors. We found that applicability of the MODIS IR CWV can be influenced significantly by the prevailing summer overcast conditions. In contrast, MODIS NIR CWV was found more sensitive to moist air masses in cloudy regions. Large-scale water vapor can transport from the southern ocean to northern China with a column loading >6cm/m². The high concentrations of aerosols mix with the water vapor, forming frequent haze pollution due to swelling effect. The interactions between water vapor and heavy pollution over East Asia can slow down the hydrological cycle in this region.

8523-66, Session PSWed
A study on aspect sensitivity of clear-air turbulence using coherent radar imaging of VHFAerospheric radar
Jenn-Shyong Chen, Chienkuo Technology Univ. (Taiwan); Jun-Ichi Furumoto, Kyoto Univ. (Japan)

Aspect angle, a measurement of aspect sensitivity of clear-air turbulence (or atmospheric refractivity irregularities), was estimated with multiple-receiver coherent radar imaging (CRI) of VHFAerospheric radar in this study. Two CRI parameters retrieved by the Capon method were utilized to derive aspect angle: brightness distribution width from vertical radar beam, and direction of arrival (DOA) of echo center from oblique radar beam. Differing from previous studies with CRI, however, a modification of brightness value has been made with a suitable radar beam weighting function before estimating the two CRI parameters. The radar beam weighting function used for correction is a Gaussian form and its standard deviation, termed beam width hereafter, is adaptive to signal-to-noise ratio (SNR) of data as well as off-beam direction angle. The use of adaptable beam width can avoid over-modifying the brightness values at the edges of the imaged map, leading to a more reliable aspect angle. The CRI-derived aspect angle was further compared with that estimated from comparison of echo powers of two different oblique radar beams. The statistical features of aspect angles obtained from the two approaches are consistent. This study has shown an application of adaptable beam width, and recommended a feasibility of improving the measurements of atmospheric parameters with CRI after removing the radar beam weighting effect from the CRI brightness value.

8523-69, Session PSWed
The effect of characteristics of partially coherent flat-topped beam truncated by a circular aperture on the M2-factor in turbulent atmosphere
Naby Hadilou, Golazin Taherabadi, Mehdii Alavinejad, Bijan Ghafary, Iran Univ. of Science and Technology (Iran, Islamic Republic of)

The presence of an aperture in a free space optical communication system causes some limitations in these systems and the laser beam propagating through such systems is usually truncated. So, it is necessary to evaluate aperture and its effects on propagation properties of laser beams. In this paper, the effects of the characteristics of a Partially Coherent Flat-topped (PCFT) beam truncated by a circular aperture on the beam quality factor (also known as M2-factor) in a turbulent atmosphere have been studied. Based on
the extended Huygens- Fresnel integral, the second-order moments of the Wigner distribution function (WDF) and also Kolmogorov spectrum the analytic expression has been derived for the M2-factor of PCFT. The numerical analysis, which is the changes of the normalized M2-factor versus the adjustable aperture parameter (the aperture radius / beam width ratio [ & r_488=a8 #8260; w, 0 ]), have been discussed precisely. It can be shown that at a given radius aperture, for larger beam order (N) better beam quality factor is achieved. Also, when the beam is full coherent or its coherence length is more than the beam width, as the aperture radius enlarges the amount of M2-factor drops and at a specific aperture radius it reaches its optimal value. After that it increases again and tends to a certain value. In addition, by decreasing both the wavelength and the beam order, the optimal value of the -factor happens at a smaller aperture radius. The obtained results are expected to be useful in long-distance free space optical communications.

8523-70, Session PSWed

The effect of characteristics of partially coherent dark hollow beam on the degree of polarization in non-Kolmogorov turbulent atmosphere

Golzin Taherabadi, Naby Hadiliou, Mehdi Alavinejad, Biljan Ghafary, Iran Univ. of Science and Technology (Iran, Islamic Republic of)

Recently, studying the degree of polarization (DOP) properties of laser beams propagating through turbulent atmosphere attracted more attention due to its significant role in optical communication. Also, in last decades, it has been revealed that there is a deviation from Kolmogorov model in the upper troposphere and stratosphere where the atmosphere is so stable. Therefore, under this circumstance, non-Kolmogorov spectrum is used. In this paper, based on the extended Huygens- Fresnel integral and by considering the non-Kolmogorov spectrum the analytical formula has been derived for the DOP of dark hollow beam (DHB) propagating through turbulent atmosphere. The numerical analysis, which is the changes of the DOP as a function of the power-law exponent (\( \alpha \)), have been investigated precisely. The obtained results show that a similar behavior is seen in all figures: The DOP decreases down to a minimum value and then its slope changes. Also, it is clear that the beam order hardly affects the DOP especially in the region of \( 3 \leq \alpha < 3.5 \). Moreover, for increasing the beam width there is a decrease of DOP. In addition, for \( \alpha < 3.3 \), increasing \( \alpha \) value close to 3, the effect of changing the beam width is negligible. Whereas for \( \alpha = 3.3 \) when the beam width increases the DOP decreases. Furthermore, one can see that if the transverse coherence width \( \alpha_y \) decreases, the amount of DOP decreases and this is more obvious for smaller \( \alpha_y \). These results are expected to be useful in free space optical communications.

8523-71, Session PSWed

Development of a land surface emissivity algorithm for use by microwave rain retrieval algorithms

Fumie A. Furuzawa, Hirokilo Masunaga, Kenji Nakamura, Nagoya Univ. (Japan)

We have been developing a data-set of global land surface microwave emissivity calculated from 9-channel Brightness Temperatures (Tbs) from the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and atmospheric profile data from Japanese 25-year Reanalysis Project (JRA-25). The surface emissivity is derived using the non-scattering radiative transfer equation for regions identified as no-rain by TRMM Precipitation Radar (PR).

An Empirical Orthogonal Function (EOF) analysis has been applied to this emissivity data-set. Emissivities at high frequencies, difficult to estimate due to high sensitivity to clouds and water vapor, are estimated from lower frequencies by using the principal components. Contributions from EOF1 to EOF4 are dominant and with the others being less than 1%. Therefore, 5 high-frequency emissivities can be estimated from the other 4 emissivities at lower frequencies with 4 principal components. For example, when 37 GHz Horizontal emissivity on June 1998 is estimated from 4 channels of 10 and 19 GHz, correlation coefficient with the original estimate is 0.93 and the result of linear fitting shows an inclination of 0.97 and a cutoff of 0.02 for global data. This estimation method is applied for each area, each land surface condition (surface type and soil wetness) and so on, in search of optimal performance of the algorithm. The advantage of using the EOF analysis as described above is to minimize the cloud contamination at high frequency Tb. A cloud-clearing method is also explored to improve the reliability of the EOFs.

8523-72, Session PSWed

A comparison of performance of automatic cloud coverage assessment algorithm for Formosat-2 image using clustering-based and spatial thresholding methods

Kuo-Hsien Hsu, National Space Organization (Taiwan)

Formosat-2 image is a kind of high-resolution satellite data, which includes one panchromatic band and four multispectral bands (Blue, Green, Red, near-infrared). An essential sector in the daily processing of received Formosat-2 image is to estimate the cloud statistic of image using Automatic Cloud Coverage Assessment (ACCA) algorithm. The information of cloud statistic of image is subsequently recorded as an important metadata for image product catalog. In this paper, we propose an ACCA algorithm with a sequence of un-supervised K-means classification, Sobel edge detection technique, thresholding technique, non-cloudy pixels reexamination, cross-band filter method, and Box-Counting fractal method. According to our previous work [Hsu, 2011], it found that the effectiveness of the proposed ACCA algorithm would be influenced by the candidate of thresholding technique. Practically, an accurate ACCA algorithm shall increase the efficiency of the time-consuming and labor-intensive manual examination by providing an accurate cloud statistic. Therefore, we qualitatively and quantitatively examine the performance of proposed ACCA algorithm using cluster-based and spatial thresholding methods. For this comparison purpose, three thresholding methods are implemented, which are Otsu’s method [Otsu, 1979], Pal and Pal’s method [Pal et al, 1989], and Change’s reexamination, cross-band filter method, and Box-Counting fractal method. According to our previous work [Hsu, 2011], it found that the effectiveness of the proposed ACCA algorithm would be influenced by the candidate of thresholding technique. Practically, an accurate ACCA algorithm shall increase the efficiency of the time-consuming and labor-intensive manual examination by providing an accurate cloud statistic. Therefore, we qualitatively and quantitatively examine the performance of proposed ACCA algorithm using cluster-based and spatial thresholding methods. For this comparison purpose, three thresholding methods are implemented, which are Otsu’s method, Pal and Pal’s method, and Change’s reexamination, cross-band filter method, and Box-Counting fractal method. According to our previous work [Hsu, 2011], it found that the effectiveness of the proposed ACCA algorithm would be influenced by the candidate of thresholding technique. Practically, an accurate ACCA algorithm shall increase the efficiency of the time-consuming and labor-intensive manual examination by providing an accurate cloud statistic. Therefore, we qualitatively and quantitatively examine the performance of proposed ACCA algorithm using cluster-based and spatial thresholding methods. For this comparison purpose, three thresholding methods are implemented, which are Otsu’s method, Pal and Pal’s method, and Change’s reexamination, cross-band filter method, and Box-Counting fractal method.
Impacts of land-use/land-cover (LULC) changes on land surface temperature (LST) in Addis Ababa, Ethiopia, based on satellite images of December 1986 and 2010 respectively

Daniel M. Mbitih, Kenya Meteorological Services (Kenya)

Urbanization has been a major force of LULC throughout human history that has had a great impact on climate change. This study examined LULC changes in the capital of Ethiopia, Addis Ababa from 1986 to 2010. Urban/built-up areas expanded dramatically, while agricultural land and forest declined. Barren land increased, mainly in the boundary areas between forest and dry agricultural fields, especially in steeply sloping areas. The observed changes in LULC were largely attributed to population pressure on the land, a rapidly growing infrastructure and poor land use planning. Changes in LULC were accompanied by changes in Land Surface temperature (LST). This could lead to an intensified urban heat island (UHI) effect in the urban areas. The abundance of forest was an important factor influencing LST. Moreover, temperature differences between the urban/built-up and the surrounding rural areas significantly widened. The study assessed the UHI spatial patterns and temporal variations in the Addis Ababa city. The urban-rural temperature differences between the urban core and its surrounding areas show a maximum difference of >20 degrees centigrade. Greening of the urban set up is highly recommended in this study.

Mapping fifty global cities’ growth using time-series Landsat data

Hasi Bagan, Yoshiki Yamagata, National Institute for Environmental Studies (Japan)

Urban growth and sprawl have drastically altered the ecosystems and ecosystem services. The objectives of this study are to using grid square method to investigate the spatial and temporal dynamics of urban growth in 50 global cities using Landsat ETM/TM imagery from 1985-2011. First, MLC classification method were used to produce land cover maps by using Landsat images from 1985’s, 1993’s, and 2007’s (completed); then intersect the land cover maps with 1-km2 grid cell maps to represents the proportion of each land cover category within each 1-km2 grid cell (ongoing); finally, combining the proportional land cover maps to investigated the relationship between land cover changes based on grid square cells for three intervals (i.e. around 1985, around 1993, and around 2007). The results obtained in Tokyo, Japan shows the Settlements area has rapidly expanded to the surrounding sub urban area which was mainly located flat areas or along the transportation lines. The area of Settlements doubled over the past two decades, increasing from 12.5% of the study area in 1987 to 23.5% in 2011. The correlation analysis in Tokyo shows strong, negatively linear relationship between the Settlements change and cropland change (r = -0.7848), suggesting that the vast area of cropland area have been converted to Settlements during the last two decades. In the next step, we will analyze the other 49 cities using 1-km2 grid cell approach and calculate the correlation coefficient matrix between the changes of land cover categories from 1985’s - 2007’s for each cities. Furthermore, we expect to compare and contrast the rates and patterns of expansion, and drivers of land cover change in 50 cities.

China’s 30m global land cover map

Peng Gong, Tsinghua Univ. (China)

The first 30 m resolution global land cover map was produced using Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data. We classified over 6600 scenes of Landsat TM data after 2006 and over 2300 scenes of Landsat TM and ETM+ data before 2006 all selected from the green season. These images cover most of the world except Antarctica and Greenland that are covered primarily by ice and snow. Most of these images came from the United States Geological Survey in level L1T (orthorectified). All these images except those in China were corrected for atmospheric effects and topographic effects. Five classifiers that are freely available were employed including the conventional maximum likelihood classifier (MLC), J4.8 regression tree classifier, Adaboost based on the J4.8 as weak classifier, random forest and support vector machine (SVM). Over 90000 training samples were collected by traversing each scene and finding the most representative and homogeneous samples. Over 40000 test samples were collected at fixed locations based on a systematic unaligned sampling strategy. Two software tools, Global Analyst and Global Mapper developed by extending the functionality of Google Earth, were used in developing the training and test sample databases by referencing high resolution images from Google Earth. A unique land cover classification system was developed that can be cross-talked to the existing United Nations Food and Agriculture Organization (FAO) land cover classification system as well as the International Geosphere-Biosphere Programme system. Using the five classification algorithms, we obtained an initial set of global land cover maps. The SVM produced the highest overall classification accuracy (OCA) of 66.4% using our test samples, with random forest (60.9%), MLC (59.4%), Adaboost (59.0%) and J4.8 (57.8%) ranked from the second to the fifth. When using a compiled set of test samples from international sources (Boston University, Fluxnet, and GLCNO), our classification results produced an OCA ranging from 49.9%–54.0% with the same rank order among the classifiers. A major achievement
8524-5, Session 1

Polarimetric analysis of coastal region using time series of Radarsat-2 images
Hsiu-Wen Wang, Kun-Shan Chen, National Central Univ. (Taiwan); Horn-Ru Liao, National Science Council (Taiwan)

Over the years, attention has been drawn on coastline changes due to concern of global warming and geo-environmental vulnerability. This study applied time series of Radarsat-2 fully polarimetric SAR images to analyze the polarimetric response of coastal region over the western Taiwan. A total of 6 data takes were acquired in 2009 covering the low tide and high tides situations. Geologically, Western coast of Taiwan is mainly a flat terrain of sedimentary structure that composes of sand and mud. The middle coast of the topography of the seabed terrain compared with the northern and southern regions is relatively high. The tidal between rise and ebb has large variations due to the seabed terrain of surface undulation. The change of sandbank has been constantly affected by monsoon and typhoon interaction effects. The four components target decomposition was applied to obtain the landcover types into surface scattering, volume scattering, and double bounce, and helix components, to investigate the tidal effect and ocean wind-wave interactions with sandbanks just off the coast. Analysis was carried out by integrating with the tidal data and relevant marine meteorology information. Based on CFAR detector, it is potentially to identify the terrain feature in more detail from polarimetric response, in particular the wave breaking zone and the oyster farming location can be determined.

8524-6, Session 1

Validation of the wetlands map derived from MODIS imagery in North America
Gegen Tana, Chiba University (Japan); Husi Letu, Tokai University (Japan); Ryutaro Tateishi, Chiba University (Japan)

Wetlands are among the world’s most important ecosystems. However, the spatial distribution of wetlands on a global scale is poorly characterized in existing global land cover datasets. A more reliable global wetlands map based on satellite data is urgently needed for global environmental change analysis. A wetlands map in North America was produced using 500 m MODIS data obtained in 2008 using the rule-based method. To assess the accuracy of the map, two types of accuracy assessment were performed. They are close proximity to water bodies. Type II wetlands are characterized by a higher vegetative component that obscures their morphology.

8524-7, Session 1

Land cover classification comparisons among dual polarimetric, pseudo-fully polarimetric and fully polarimetric SAR imagery
Bhogendra Mishra, Junichi Susaki, Kyoto Univ. (Japan)

In this paper, an approach is proposed that predicts fully polarimetric data from dual polarimetric data, and then applies selected supervised algorithm for dual polarimetric, pseudo-fully polarimetric and fully polarimetric dataset for the land cover classification comparison. A regression model has been developed to predict the complex variables of VV polarimetric component and amplitude independently using corresponding complex variables and amplitude in HH and HV bands. Support vector machine (SVM) is implemented for the land cover classification. Coherence matrix and amplitude were used for all dataset for the land cover classification independently. They are used to compare the data from different perspective. Finally, a post processing technique is implemented to remove the isolated pixels appeared as a noise. AVNIR-2 optical data over the same area was used as ground truth data to access the classification accuracy. The result from SVM indicates that the fully polarimetric mode gives the maximum classification accuracy followed by pseudo-fully polarimetric and dual polarimetric datasets using coherency matrix input for fully polarimetric image and pseudo-fully polarimetric image and covariance matrix input for dual polarimetric image. Additionally, it is observed that pseudo-fully polarimetric image with amplitude input does not show the significant improvement over dual polarimetric image with same input.

8524-8, Session 1

A compound method for automatically extracting plateau wetlands from satellite imagery
Jay Gao, The Univ. of Auckland (New Zealand); Huan Li, Hohai University (China)

Timely information on wetland distribution can be effectively acquired by means of remote sensing. A Landsat TM image recorded on 17 July 2009 (row: 36; column: 134) at a spatial resolution of 30 m was used to map wetlands in Maduo County of northwestern Qinghai Province with a combined method of thresholding, tasselled cap transformation and vegetation indexing. The wetlands found in the study area fall into two broad types, I and II. Type I wetlands are characterized by a close proximity to water bodies. Type II wetlands are characterized by a higher vegetative component that obscures their morphology. Thresholding was used to map type I wetlands from TM5. Tasseled Cap transformation was used to map type II wetlands. With the assistance of NDVI, snow was then removed, leaving only grassland and type II wetland to be separate. Type 1 wetland was mapped at 832 km?. The second type of wetland was mapped at 422.97 km?. A total of 1254.97 km2 wetlands were mapped. Comparison with the raw color composite of the same image reveals that the mapping has been accomplished quite accuracy. More research will be undertaken to compare the classified results with those obtained with supervised and unsupervised results. Both thresholding and Tasseled Cap transformation are found to be effective at detecting different types of wetlands in the plateau environment.

8524-9, Session 1

Monitoring land and water use in Nha Trang, Vietnam by remote sensing technique
Phan Minh-Thu, Wageningen Univ. (Netherlands); Michael E. Schaepman-Strub, Zurich Univ. of Applied Sciences (Netherlands); Rik Leemans, Wageningen Univ. (Netherlands); Nguyen Tac-An, Tong Phuc Hoang-Son, insitute of Oceanography (Viet Nam)

By upgrading Nha Trang city, developing its economy and expanding tourism, rapid changes of land and water use occurred. These
impacted environmental quality as well as human life. A data analysis of multiple remotesensing images indicated that the status of land and water use were oriented to develop aquaculture and agriculture in the early period (1990s), but urbanization was more contributed to these changes in the later period (2000s). In the early period, area of agriculture and inland aquaculture reached their maximum land-use capacity. In this period, houses were built in the city centre and along the national road. In the later period, urban regions have been considerably expanded by converting agricultural and unused land. In addition, the developments of marine culture as well as navigation (goods and fishing ports) and tourism increased effects of water and islands uses. Furthermore, the changes of land and water use were also related with degrading water quality. These days, this water quality is improving again. Different kinds of remote sensing images, abundance of land and water use types and their size were negative impacted on processing analysis. However, due to the limiting active time of satellite system, the using multiple remote sensing images would be contributed in the long term monitoring of land and water use as well as the assessment of environmental quality for sustainable development in Nha Trang.

8524-11, Session 1

**PolSAR change detection applied to specific land cover type**

Meng Liu, Hong Zhang, Chao Wang, Bo Zhang, Fan Wu, Ctr. for Earth Observation and Digital Earth (China)

**SAR** Change detection involves four major steps: pre-processing filter and co-registration, difference map extraction, threshold segmentation, and image fusion. In the terms of difference map extraction, it is shown that the method using PolSAR data performs better than the method using single channel SAR data [1] [2]. However, we still cannot distinguish the land cover type before and after the change from the difference map generated by the PolSAR change detection method. In the majority of applications, we do not need all of the changes area areas, but changed areas from specific class i to class j. Therefore, the method of applying land cover type information of PolSAR to change detection deserves more studies.

In this paper, we will propose a novel PolSAR change detection method applied to specific land cover type. Firstly, a polarimetric coherency matrix is used to simultaneously take into account the full polarimetric information from both images [3]. Then, a generalized likelihood ratio test (GLRT) statistic for equality of two polarimetric coherency matrices is considered and a maximum likelihood (ML) distance measure is derived [4] [5]. When the change from class i to class j has occurred, this distance measure is expected to be high. Two Radarsat-2 fully polarimetric images in Suzhou city, China, acquired on April 9, 2009 and June 15, 2010 separately, are used for our experiment. It is shown that the proposed distance will give a good performance to quantify the difference between the statistical characteristics of PoSAR images.

**REFERENCES**


8524-13, Session 2

**Estimation of soil moisture with the combined L-band radar and radiometer measurements**

Jiancheng Shi, Institute of Remote Sensing Applications (China)

Soil moisture is a key parameter in numerous environmental studies, including hydrology, meteorology, and agriculture. It plays an important role in the interactions between the land surface and the atmosphere, as well as the partitioning of precipitation into runoff and ground water storage. Therefore, the spatial and temporal dynamics of soil moisture are important parameters for various processes in the soil-vegetation-atmosphere-interface. The Soil Moisture Active Passive (SMAP) with both Active/Passive L-band instruments has been approved by NASA for monitoring global soil moisture and freeze/thaw. The SMAP instrument combines radar and radiometer subsystems. The radar operates with V, H, and HV transmit-receive polarizations, and uses separate transmit frequencies for the H (1.26 GHz) and V (1.29 GHz) polarizations. The radiometer operates with V, H and U (third Stokes parameter) polarizations at 1.41 GHz.

In attempt to use the active or passive microwave remote sensors for estimation of soil moisture, we are mainly facing two common problems: effects of surface roughness and vegetation cover. Natural variability and the complexity of the vegetation canopy and surface roughness significantly affect the sensitivity of backscattering and brightness temperature to soil moisture. Backscattering and brightness temperature signals from vegetated areas is a function of water content and its spatial distribution as determined by vegetation structure and underlying surface conditions including surface roughness parameters and dielectric properties. Due to the limited observations from either passive or active measurements alone, an ill condition, the number of measurements and equations are less than the number of unknowns, is expected. It results in the uncertainties in estimation of soil moisture.

In this study, we develop a combined active/passive technique to estimate surface soil moisture with the focus on the short vegetated surfaces. We first simulated a database for both active and passive signals under SMAP's sensor configurations using the radiative transfer model with a wide range of conditions for surface soil moisture, roughness and vegetation properties that we considered as the random orientated disks and cylinders. Using this database, we developed 1) the techniques to estimate surface backscattering and emission components and 2) the technique to estimate soil moisture with the estimated surface backscattering and emission components. We will demonstrate these techniques with the model simulated data and its validation with the airborne PALS image data from the soil moisture SGP’99 and SMEX’02 experiments.

8524-14, Session 2

**Calibration of a land surface model using microwave remote sensing observations**

Hui Lu, Tsinghua Univ. (China)

A complex land surface model is generally characterized by a multitude of parameters, which are not exactly known a priori. In order to assess performance and to improve predictions, land surface models are routinely calibrated against measurements. Currently, in situ observations are generally used to calibrate the model, which limits both the application range and accuracy of model. In this study, we calibrated a land surface model (SiB2) using microwave remote sensing observations, which were available globally and closely related to the land surface status.

The multi-objective calibration method consists of three steps. The first step is to minimize the number of optimizing variables with a parameter conversion equation. The second step is to build the connection between the land surface status and the remote sensing data using a radiative transfer model. The final step is to minimize the cost function which is calculated by targeted parameters and remotely sensed signals.

We validated the calibration method with a well-designed field experiment, in which ground-based microwave radiometers were adopted to provide remote sensing observations. The footprint of radiometers located in a well-controlled plot, in which the
heterogeneity was minimized and the scale of remote sensing signals and in situ observation was matched. The parameters obtained from our method were close to those measured in situ. Comparing simulated results to in situ observation, we found that both parameter sets are equivalent with regards to the prediction of soil moisture status.

8524-15, Session 2
Assimilation of surface soil moisture into catchment hydrologic model via ensemble Kalman smoother
Fangni Lei M.D., Wuhan Univ. (China); Chunlin Huang, Cold and Arid Regions Environmental and Engineering Research Institute (China); Huanfeng Shen, Wuhan Univ. (China)
With the SMOS (Soil Moisture and Ocean Salinity) satellite launched and the upcoming SMAP (Soil Moisture Active and Passive Mission) mission carried out, satellite-based surface soil moisture observations have been widely paid attention in the field of hydrology, agriculture, and meteorology. This measurement can not only be used to validate the hydrologic model, but also can improve the hydrologic predictions through data assimilation method which could be a compensation for impact model physics, uncertain forcing data and inaccurate parameters. In this paper, the synthetic surface soil moisture data are assimilated into a physical-based hydrological model, the Soil and Water Assessment Tool (SWAT), to evaluate its impact on hydrological states (such as profile of soil water content, surface runoff, evapotranspiration, and streamflow) and model parameter (CN2) using the ensemble Kalman smoother (EnKS) method in the upstream of Heihe basin, Northwest China. The preliminary results show that assimilating surface soil moisture observations can moderately improve the profile soil water content. In the meantime, surface runoff has got some improvements, while the evapotranspiration and streamflow have little changes due to the imperfect model physics in SWAT model. Thus, surface soil moisture updating through data assimilation can be used to combine remote sensing observations and hydrological model together to achieve better model simulation, reduce predictive uncertainties and make decisions for water resource management at watershed scale. Moreover, this study also proves that the EnKS is an effective and ease-to-use method for hydrological application.

8524-19, Session 2
Time series microwave emission properties of snow-covered surface in South China both using model simulation and observations
Lingmei Jiang, Beijing Normal Univ. (China)
In the winter of 2008 and 2011, heavy snow events occurred in South China, which caused lots of economic losses. Current remote sensing techniques failed to provide snow cover information, since optical remote sensing is limited due to the existence of thick clouds. While present passive microwave remote sensing of snow usually estimates snow depth or snow water equivalence only for dry snow surface. It is not valid to determine snow cover when the surface was covered with wet snow in South China.

The current studies on wet snow detection in South China included the work of Li et al. (2009) and Jin et al. (2011). Both of their work mainly involved limited area including Hunan province and Wuhan, respectively. Li et al. (2009) used the diurnal difference of 37 GHz brightness temperature in vertical polarization. Jin et al. (2011) applied the polarization difference at 10 GHz and the spectral difference between 23 and 89 GHz in vertical polarization. However, the physical principle to map wet snow cover by passive microwave remote sensing is still not clear.

This paper proposed here is to analyze time series emission properties of snow covered surface in South China both using snow emission model and ground observations. In South China, snow-covered surface at daily was in wet snow condition due to the air temperature higher than 0°C, while snow-covered surface at night could be frozen. Therefore, this work is to make clear the emission character of bare soil, wet snow and refrozen snow surface, respectively. A transition-layer model will be utilized to model the emission of wet snow and frozen snow. These two categories of snow showed obvious different emission behavior. In addition, we collected weather station observations, IMS (Interactive Multi-sensor Snow and Ice Mapping System) product, snow fraction estimated by Shi et al. (2012) using MODIS reflectance data during snow period of 2008 and 2011. And both AMSR-E and FY3B/MWRI are used for the analysis. This work will help to establish a new snow cover mapping technique that can be applied in South China.

8524-20, Session 2
Airborne active and passive L-band measurements using PALS instrument in SMAPVEX12 soil moisture field campaign
Andreas Colliander, Simon H. Yueh, Seth L. Chazanoff, Steven J. Dinardo, Ian O’Dwyer, Jet Propulsion Lab. (United States); Thomas J. Jackson, U.S. Dept. of Agriculture (United States); Hester Mathison, Agriculture and Agri-Food Canada (Canada); Paul Bullock, University of Manitoba (Canada); Grant Wiseman, Agriculture and Agri-Food Canada (Canada); Aaron Berg, University of Guelph (Canada); Ramata Magagi, University of Sherbrooke (Canada); Eni G. Njoku, Jet Propulsion Lab. (United States)
NASA’s (National Aeronautics and Space Administration) Soil Moisture Active Passive (SMAP) Mission is scheduled for launch in late 2014. The objective of the mission is to globally map soil moisture and freeze/thaw state. Merging of active and passive L-band observations of the mission will enable unprecedented combination of accuracy, resolution, coverage and revisit-time for soil moisture and freeze/thaw state retrieval. For pre-launch algorithm development and validation the SMAP project and NASA are coordinating a field campaign named as SMAPVEX12 (Soil Moisture Active Passive Validation Experiment 2012) together with Agriculture and Agri-Food Canada in the vicinity of Winnipeg, Canada for June–July, 2012. The main objective of SMAPVEX12 is to acquire two days of imagery that covers long-time series with varying soil moisture and vegetation conditions over aerial domain of multiple parallel lines. The coincident active and passive L-band data will be acquired using the Passive Active L-band System (PALS), which is an airborne radiometer and radar developed for testing L-band retrieval algorithms. For SMAPVEX12

8524-21, Session 2
A simple method for estimating irrigation area using HJ-1A/1B CCD data
Zhongli Zhu, Fan Du, Beijing Normal Univ. (China)
Irrigation area is an important parameter for water resource management in the arid regions such as the western China. Unfortunately there is still no good ways for monitoring the processes of irrigation practices in large area due to the small farm plots which belong to different peasant families and they are irrigated in different time in China. The CCD cameras onboard HJ-1A/1B satellites, which have a 2-day revisit period and 30 m spatial resolution, provide us with a good resolution to fix this problem. This paper selected the Zhangye Oasis in Gansu province in western China as the study area, using Perpendicular Drought Index (PDI) change detection method, which based on NIR-RED reflectance and threshold of PDI change is about 0.3, to extract the time and spatial distribution of the irrigation area during the crop season. The retrieved irrigation areas were compared with the in-situ investigation data from parts of the irrigation districts. The experimental results show that this method can efficiently monitor the processes of the irrigation, not only give us the spatial distribution, but also the irrigation time. The accuracy is more than 90 percent, which mainly affected by the afternoon and night irrigation, and cloudy/raining days during the experiment period.
PALS will be installed on a Twin Otter aircraft. The instrument will make brightness temperature and backscatter measurements over the experiment domain nominally every three days over a period of about 45 days. The presentation will include description of the measurement flights and an evaluation of the radiometric performance of the PALS observations.

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8524-21, Session 2
A nested global-local hydrological model for large scale flood forecasting using remote sensing satellite data: a contribution to monitoring global environmental change
Amir AghaKouchak, Ali Mehran, Navid Nakhjiri, Univ. of California, Irvine (United States)

This paper aims to contribute to modeling hydroclimatic extremes and understanding the complex Earth system processes using satellite data sets. A nested hydrological modeling framework is proposed for quasi-global flood forecasting using satellite data. The proposed modeling framework consists of two steps. Step 1: A 0.25 degree conceptual-probabilistic global hydrological model is proposed to identify areas with high probability of flooding. Step 2: A deterministic semi-distributed model, nested within the global, is suggested for detailed flood analysis in watershed (local) scale. Having a fully nested global-local model, the local model can be activated only for areas identified as high risk in the first step. Satellite-based precipitation, snow covered areas, evapotranspiration and soil moisture data, derived from multiple sensors, are used as input data. The simulated runoff using the presented model is validated with the Global Runoff Data Center measurements. The results indicate that the model can provide reasonable probability of flooding, and magnitude of peak flow. The model can be used to monitor global environmental changes due to large scale flooding events. Efforts are underway to use this model for an early flood warning system that can provide probability of flood events and their uncertainties.

8524-37, Session 2
Analyzing the inundation patterns in Asia floodplains by passive microwave data
Haolu Shang, Institute of Remote Sensing Applications (China) and Technische Univ. Delft (Netherlands); Jia Li, Institute of Remote Sensing Applications (China) and Wageningen Univ. (Netherlands); Massimo Menenti, Technische Univ. Delft (Netherlands)

Soil water saturation condition is an essential factor that indicates the possible temporal and spatial development of inundation in floodplains. To monitor wetness condition over a long period of time and large areas, passive microwave data is used to study the inundation pattern of large floodplains in Asia, such as the Poyang Lake floodplain. The polarization difference brightness temperature at 37GHz is sensitive to the water extension even under dense forest. However, the mixing of signals from open water, bare soil and vegetation makes it difficult to obtain the soil-water saturation conditions from 37GHz data. That is because 37GHz microwave emission is attenuated by the vegetation canopy, which shows seasonal changes in Asia floodplains. We developed a linear mixing model to eliminate the signal from vegetation and derive the soil-water saturation condition from 37GHz data. Vegetation attenuation factors, in terms of vegetation fractional area and LAI, have been estimated by correlation with the NDVI. Thus the vegetation attenuation function is built according to the relationship between 37GHz data and NDVI of agricultural area, with the help of Harmonic analysis of time series to obtain continuous NDVI time series. Comparing the soil-water saturated area from 37GHz and water extension area of Poyang Lake from SAR image data at higher spatial resolution, our result shows a good fit with SAR data but relative higher values.

8524-22, Session 3
Monitoring surface climate with its emissivity derived from satellite measurements
Daniel K. Zhou, Allen M. Larar, Xu Liu, NASA Langley Research Ctr. (United States)

Presented here is the global surface IR emissivity retrieved from the Infrared Atmospheric Sounding Interferometer (IASI) measurements under “clear-sky” conditions. We describe the retrieval algorithm and demonstrate the surface skin temperature and emissivity retrieved with IASI measurements; we also demonstrate that surface emissivity from satellite measurements can be used in assistance of monitoring global surface climate change. Monthly mean surface properties with a spatial resolution of 0.570.5 degrees of latitude-longitude are produced using last 5-year IASI measurements to derive a trend.

8524-23, Session 3
Estimation and monitoring heat discharge rates using Landsat ETM+ thermal infrared data: a case study in Unzen geothermal field, Kyushu, Japan
Md. B. Mia, Yasuhiro Fujimitsu, Kyushu Univ. (Japan); Chris Bromely, GNS Science (New Zealand)

The Unzen geothermal field, our study area is active fumaroles, situated in Shimabara Peninsula of Kyushu Island in Japan. Our prime objectives were: (1) to estimate radiative heat flux (RHF); (2) then, to work out the relationship of RHF with the total heat loss; (3) after that, to estimate satellite infrared based heat discharge rate (HDR), and (4) finally, to monitor RHF as well as HDR of the study area from 2000 to 2009 by using seven sets of thermal infrared data (TIR) of Landsat 7 images. On the basis of radiometric calibration, atmospheric correction and spectral emissivity, we computed the land surface temperature (LST) using mono-window algorithm. LST showed a strong correlation with RHF of this region. We used the Stefan-Boltzmann equation for calculating RHF of those satellite TIR images. We found that the maximum RHF was about 251 W/m² in 2005 and minimum was about 27 W/m² in 2001. The highest total RHF of the study area was about 39.1 MW in 2005 and lowest was about 12 MW in 2001. We discovered that the estimated RHF was about 15.7 % of HDR from our studies. We applied this percentage to estimate heat discharge rate in Unzen geothermal area. The monitoring results showed a single fold trend of HDR from 2000 to 2009 with highest about 32.62 MW in 2005 and lowest about 78 MW in 2001. In conclusion, TIR remote sensing could be the best option for monitoring heat losses from fumaroles with high efficiency and low cost.

8524-24, Session 3
Estimation of global ET-Index from satellite imagery for water resources management
Masahiro Tasumi, University of Miyazaki (Japan); Reiji Kimura, Tottori University (Japan); Masao Moriyama, Nagasaki University (Japan); Richard G Allen, University of Idaho (United States); Aiko Fujii, University of Miyazaki (Japan)

This paper presents the algorithm to estimate Evapotranspiration Index (ET-Index), developed as a research product of GCOM-C1 satellite of the Japan Aerospace Exploration Agency (JAXA). ET-Index is equivalent to widely used “Crop Coefficient” in field of irrigation engineering, defined as the actual evapotranspiration normalized for the weather condition. The ET-Index is convertible to actual quantity of evapotranspiration using weather information. ET-Index is estimated primarily by land surface temperature image of satellite, with some additional inputs including Digital Elevation Model (DEM) and global wind speed reanalysis data. The final product will be cloud-free global daily ET-Index map having 500m or 1km spatial resolution, in case the method is applied to GCOM-C1 or MODIS imagery. The algorithm estimates ET-Index by using surface temperature as
Semi-analytical land surface temperature estimation algorithm for GCOM-C/SGLI

Masao Moriyama, Nagasaki Univ. (Japan)

So far the land surface temperature estimation algorithm are classified into the regression method and the semi-analytical method. The regression method is so called Split-Window method which is the modification of the sea surface temperature estimation algorithm and used for MODIS and AATSR data analysis. The semi-analytical method is the combination of the atmospheric correction of the satellite observed radiance and the semi-analytical temperature and emissivity separation scheme, this method is used for ASTER data analysis. The temperature and emissivity separation is the analytic solution of the simultaneous equation of the land leaving radiance at each observation spectrum which is computed from the atmospheric correction however the number of unknown is one more than the number of equations, so that many approximation have been adopted.

The proposed algorithm use the Split-Window algorithm as the constraint equation of the simultaneous leaving radiance equation and make the number of the unknown and the equation are the same. To make this algorithm, the Split-Window equation which incorporated the emissivity explicitly is developed and the Newtonian iteration based efficient solving method is also developed. From the numerical simulation, the temperature estimation RMS error is up to 1.5[K] and from the MODIS based implementation, the estimated temperature shows the good correspondence with MODIS day/night algorithm based temperature.

Remote-sensing-based continuous estimation of regional evapotranspiration by improved SEBS model

He Chen, Dawen Yang, Tsinghua Univ. (China)

Remote sensing (RS) has been considered as the most promising tool for evapotranspiration (ET) estimation at regional scale. Many studies have been conducted to estimate ET using RS data. However, large errors implied in the process of extrapolating instantaneous latent heat flux derived at satellite over-passing time to daily ET inevitably constrains the feasibility of RS models. In this study, we improved Surface Energy Balance System (SEBS) model by replacing the instantaneous inputs with daily representative values to estimate daily ET directly. A further strategy was added to the model for estimating ET during cloud-contaminate period using moving window averaged Bowen ratio. One merit of this improved model is that the calculation of daily ET can be avoided by means of instantaneous input from ground observations, which is insufficient at regional scale. The other merit is that the cloud-free constrain of ET estimation based on RS data is circumvented through an interpolation approach, which makes continuous ET estimation possible. For the purpose of model performance evaluation, the model was tested at the Weishan flux site in the North China plain from 2006 to 2007. Two-year continuous simulation results show that the model has a good performance for daily ET estimation with a deterministic coefficient of 0.59 and a bias of 3%. Then the model was applied to the 4448 km² Weishan Irrigation District from 2002 to 2007 at 1-km spatial resolution. Comparison with both regional water balance model and distributed hydrological model demonstrates the potential of this model for monitoring land surface ET and water budget.

Operational retrieval results of land surface temperature from the first Korean geostationary satellite: COMS data

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Korea Meteorological Administration successfully launched the first geostationary multi-purpose satellite on 27 June 2010. COMS (Communication, Oceanic, and Atmospheric Satellite), which is located at an altitude of 36,000 km above the Earth’s equator and at a longitude of 128.2°E, is successfully performing the duties of meteorological and oceanic observations and communications services. Land surface temperature (LST) is a one of the most difficult surface variables to observe regularly due to the strong spatio-temporal variation. At present, satellites remote sensing data are regarded as the only available operational systems capable of collecting cost-effective LST data at spatial and temporal resolutions appropriate to modeling applications. In this study, we will present the operational retrieval results of land surface temperature (LST) from the COMS data. The split-window LST retrieval algorithm was developed from the synthetic LST match-up data through the radiative transfer simulations under various atmospheric profiles (TIGR data), satellite zenith angle (SZA), spectral emissivity, and surface lapse rate conditions using MODTRAN 4. The bi-weekly emissivity of two split-window channels were retrieved with the vegetation coverage method using land cover map, look-up table of emissivity, and normalized difference vegetation index. The accuracy of COMS LST was evaluated with the co-located MODIS LST data within ±5 minutes. The evaluation results showed that the COMS LST is reasonably well matched with the relatively cold MODIS LST but it is systematically higher than MODIS LST especially for the LST higher than 290K without regard to the geographic location and seasons. The reasons for the systematic overestimation of COMS LST and correction results will be presented.

Regression imputation with ground air temperature for the satellite-based lake and reservoir temperature database in Japan

Hideyuki Tonooka, Ibaraki Univ. (Japan)

Water temperature monitoring for inland water bodies like lakes and reservoirs is important in the aspects of biodiversity conservation, and global warming monitoring. However, most of inland water bodies except for a few large water bodies have not fully or never been monitored on water temperature, partly because in-situ temperature measurements are not easy for small water bodies which are widely scattered and variously managed by individuals, companies, governments etc. Thus, the satellite-based lake and reservoir temperature database in Japan (SatLARTD-J) has been under development since 2009. At present, the database contains surface temperature data for about 900 water bodies which were retrieved from thermal infrared (TIR) images of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument onboard NASA’s Terra satellite, but its temporal resolution is only twice per year in average. In order to improve this, the author demonstrates regression imputation for SatLARTD-J using ground air temperature data provided from the Automated Meteorological Data Acquisition System (AMeDAS) operated by Japan Meteorological Agency. The validation study using in-situ data from two Japanese lakes indicates that an expected imputation error will be about 2 deg. C.
8524-30, Session 3

Evaluation of single-source, dual-source algorithms for the remote sensing of evapotranspiration

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The basic physics of determining land evaporation with multispectral radiometric data is the principle of energy conservation at the evaporating surface, but energy flux densities need to be parameterized using the variables which can be actually captured by radiometric measurements. Both observations of surface temperature and of soil water content are used for this purpose. Different data sets have been experimentally developed and documented across a range of complexity. We have evaluated algorithms of three types: a) the ET vs. LST scale is established for each data set on the basis of image statistics; b) the ET vs. LST scale is established by inverting a combination equation for two wet and dry limiting conditions; and c) soil and foliage evaporation is calculated directly (dual source models). The evaluation was carried out over different landscapes ranging from desert - oasis system spanning the entire range of water availability and plant conditions and more humid landscapes using data collected from flux towers both in China and in Europe. The results show that methods based on image statistics are found only applicable to small areas with invariant atmospheric and surface aerodynamic conditions. Methods from the first two categories cannot be used to areas (or images) that no contrast exists in surface moisture conditions. For partially covered surface dual-source models give a better agreement with measurements if soil and foliage temperatures can be obtained in prior, or if soil water content is taken into account in the parameterization of surface resistance.

8524-31, Session 3

Analysis of microwave backscatter measured by radar altimeter on land to study surface aerodynamic roughness

Le Yang, Qinhuo Liu, Institute of Remote Sensing Applications (China)

The aerodynamic surface roughness $z_0$ is a key parameter for climate and land-surface models to study surface-atmosphere exchanges of mass and energy. It is a function of the size and spacing of surface roughness elements and is typically determined at point locations in the field from wind velocity profiles. The roughness length is difficult to estimate without wind speed profile data, therefore, it is generally assumed to be constant for a given landscape configuration. While theoretical formulations of roughness have been developed in terms of canopy attributes such as frontal area, height, and drag coefficient, they become intractable at regional to global scale simulation domains.

This paper discusses the potential of radar altimetry to characterize the bare surface roughness in arid or semi-arid regions. The radar altimeter is designed to measure the sea level at the nadir point of satellite, which also provides the backscatter coefficient of the land surface at nadir view, besides range.

The Advanced Integral Equation Model (AIEM) model, which has been developed to describe backscattering over bare soil surfaces, is employed to simulate the backscatter coefficient versus the surface roughness at vertical and oblique observation angles. The microwave backscatter measured at the nadir view is more sensitive to the surface roughness than that at the oblique observation. The backscatter measurement at Ku and C band of altimeter Jason1 is analyzed with the ground measured aerodynamic surface roughness at Hehe watershed of China. The relationships were found between altimetry sigma0 and $z_0$, demonstrating the potential to map $z_0$ for large vegetation-free areas from orbit using radar systems.

8524-32, Session 4

The development of microwave vegetation index for SMOS applications

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Monitoring global vegetation can be of importance in understanding land surface processes and their interactions with the atmosphere, biogeochemical cycle, and primary productivity. The normalized difference vegetation index (NDVI) derived from optical satellite sensors and mainly dependent on the green leaf material of the vegetation cover. For microwave derived vegetation indexes, Becker and Choudhury proposed the normalized microwave polarization difference index (MPDI) for a given frequency. Recently, the microwave emissivity difference vegetation index (EDVI) was developed for dense forest conditions using 19 GHz and 37 GHz observations. Ideally, we would like the vegetation index derived from satellite measurements to be independent of background soil and atmospheric conditions and to be only dependent on the vegetation properties. At low frequencies, the atmospheric effects are expected to be much less than at higher frequencies. The Soil Moisture and Ocean Salinity (SMOS) mission has been launched in 2009 and has provided global microwave brightness temperature observations at L-band, in dual polarization and a range of viewing angles.

The microwave emission signals at low frequencies can typically be described by the $\omega-\tau$ model that is derived from a 0th-order radiative transfer solution and the atmospheric effects are expected to be much less. At the passive microwave footprint scale, the observed vegetation canopy signals represent the overall effect of the mixture of different vegetation canopy types present. When many different types of vegetation canopies with different scatter sizes, shapes and orientations are averaged, we may reasonably assume that there is no significant impact of the polarization dependence of the vegetation signals. For minimizing the effect of soil emission signals, we generated a simulated multi-angular surface emission database at L-band using the surface emission model - Advanced Integral Equation Model. This database included a wide range of the volumetric soil moisture and surface roughness.

In this study, we developed a new microwave vegetation index using L-band observations. The basis of the approach is that the bare surface emission signals of a surface for two adjacent view angles are highly correlated and can be well described by linear function with a coefficient that only depends on the pair of view angles to be used. We demonstrated that MVI is positively correlated to LAI and that it is affected only by the vegetation properties. To evaluate the microwave vegetation index, we compared MVI with the LAI measurements derived from BARC for the year 1980. Comparisons of the vegetation index and LAI showed that the general distribution and the change patterns of the MVI are consistent with those of LAI derived by the optical sensor. However, their range of values in a region and responses to time change can be significantly different. These variations are associated with land cover type and are due to the differences in sensitivity of optical and microwave observations to different parts of vegetation canopy. Further studies utilizing modeling and field verifications are needed for the quantitative descriptions on how to retrieve soil moisture minimizing the vegetation effects and how to derive the important useful vegetation parameters such as biomass or other properties.

8524-33, Session 4

Calibration and validation of Landsat-based time-series of persistent green-vegetation fraction for Australia

Kasper Johansen, The Univ. of Queensland (Australia); Tony Gill, NSW Office of Environment and Heritage (Australia); Peter Scarth, Dept. of Environment and Resource Management (Australia); Stuart Phinn, The Univ. of Queensland (Australia); Rebecca Trethwick, Dept. of Environment and Resource Management (Australia)
The AusCover remote sensing data archive and access capability (www.auscover.org.au) was formally launched in 2010 and is one of several facilities of the $55m government funded Terrestrial Ecosystem Research Network in Australia. The aim of AusCover is to deliver consistent national time-series of remotely sensed biophysical parameters to support ecosystem research and natural resource management communities in Australia. These remote sensing products are being designed for Australian conditions to enable assessment of how environmental variables change over time. National remote sensing time-series datasets are accompanied by consistently formatted metadata, which are considered to be equally important to image products. All datasets are made publically accessible and retrievable through the online AusCover data portal (http://data.auscover.org.au/). A major focus area of AusCover is remotely sensed data calibration and validation based on existing and new collections of high spatial resolution airborne LiDAR, hyper-spectral and field data. This paper provides an overview of the AusCover facility, describes completed airborne LiDAR, hyper-spectral and field data campaigns for calibration and validation of Australian image products, and presents the calibration and validation routines used for the production of a Landsat-5 TM and Landsat-7 ETM+ based time-series of persistent green-vegetation fraction (PGF) for Australia with annual coverage from 2000-2010. Over 800 field observations across Australia and full waveform LiDAR data captured over 250 plots were used to validate the PGF product (RMSE = 0.05). The PGF time-series product will be used to identify tree clearing and evaluate the effectiveness of management activities in Australia among many other applications.

**8524-34, Session 4**

**A decadal observation of vegetation dynamics using multi-resolution satellite images**

Yang-Sheng Chiang, Kun-Shan Chen, Chang-Jen Chu, National Central Univ. (Taiwan)

Vegetation cover not just affects the habitability of the earth, but also provides potential terrestrial mechanism for mitigation of greenhouse gases. This study aims at quantifying such green resources by incorporating multi-resolution satellite images from different platforms, including Formosat-2(RSI), SPOT(HRV/HRG), and Terra(MODIS), to investigate vegetation coverage ratio (VCR) and its inter-/intra-annual variation in Taiwan. Given different sensor capabilities in terms of their spatial coverage and resolution, infusion of NDVI at different scales was used to determine fraction of vegetation cover based on NDVI. Field campaign has been constantly conducted on a monthly basis for 6 years to calibrate the threshold for the presence of vegetation cover, with test sites covering IPCC-defined land cover types of Taiwan. Based on the proposed method, we analyzed spatio-temporal changes of VCR for the entire Taiwan Island. A bimodal sequence of VCR was observed for intra-annual variation based on MODIS data, with level around 5% and two peaks in spring and autumn marking the principal dual-cropping agriculture pattern in southwestern Taiwan. Compared to anthropogenic-prone variation, the inter-annual VCR (Aug.-Oct.) derived from HRV/HRG/RSI reveals that the moderate variations (3%) and the oscillations were strongly linked with regional VCR pattern and major disturbances resulting from extreme weather events. Two distinct cycles (2002-2005 and 2005-2009) were identified in the decadal observations, with VCR peaks at 87.60% and 88.12% in 2003 and 2006, respectively. This time-series mapping of VCR can be used to examine vegetation dynamics and its response associated with short-term and long-term anthropogenic/natural events.

**8524-35, Session 4**

**Characterizing vegetation dynamics in forestland of Java using MODIS time-series imagery: a monitoring approach of ecological resources in regional scale**

Yudi Setiawan, Kunihiko Yoshino, Univ. of Tsukuba (Japan)

Most studies on forest cover change have been focused on deforestation or forest degradation as a single pathway, meanwhile; in the context of changes in net area of the forestland are the sum of several processes such as deforestation, reforestation/afforestation, regeneration of previously deforested areas, and the changing spatial location of the forest boundary. Remote sensing technology seems to be a powerful tool to provide information required following that concerns. A comparison imagery taken at the different dates over the same locations for assessing those changes have tended to be limited by the vegetation phenology and land-management practices, consequently, the simultaneous analysis seems to be a way to deal with the issues above, as a means for better understanding of the dynamics changes in forestland. In this study we examine the feasibility of using long-term MODIS images for detecting and monitoring the changes in forestland, and then, to identify systematically the pathway of cover changes in the forestland. From the identification of the dynamics changes, totally 59 patterns were identified during period 2001-2007, which broadly represent the major change pathway in forestland of Java Island. Characterizing the pathways of forest cover change in forestland, which is demonstrated in this paper, will allow further identification for the range of proximate and underlying factors of the forest cover change that can help to develop useful policy interventions to reduce deforestation rate and encourage forest regrowth.

**8524-36, Session 4**

**SAR-based monitoring of plantation area in peatland forests of Sarawak, Malaysia**

Ram Avtar, Hideki Kobayashi, Hadi Fadai, Rikie Suzuki, Japan Agency for Marine-Earth Science and Technology (Japan)

With the increase in the global demands for food and bio-fuels, the plantation is increasing. Plantation is the major derivers of deforestation and biodiversity loss in Southeast Asian forests. A number of research papers have demonstrated the applicability of SAR data to monitor terrestrial ecosystem in tropical countries without limitations of clouds. The objective of this study is to reveal the dependency of plants structural types on SAR backscattering properties to identify various plantation species such as Acacia and Oil Palm plantation in peatland forests of Sarawak, Malaysia. This study is focused on role of ALOS/PALSAR and TerraSAR-X data to differentiate plantation species. Field data and high resolution optical data have also been used for the validation of the SAR generated plantation area map.

**8524-38, Session 4**

**On the high-fidelity monitoring of C3 and C4 crops under nutrient and water stress**

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Earth’s fresh water supplies are used predominantly in agriculture. This situation makes the effective monitoring of crops’ responses to nutrient and water stress essential not only from an economical, but also from an ecological point of view. An underestimation of their nutrient and water requirements may lead to reduced yields, while an overestimation may lead to adverse environmental effects such as the contamination (e.g., due to the excessive use of fertilizers) and even depletion of limited fresh water supplies. The most important plant crops are either C3 or C4 plants. These two classes of plants have different photosynthetic and morphological characteristics that result in distinct responses to stress factors. These responses are strongly correlated with their red edge, the s-shaped curve in the 680-800nm region of their reflectance spectra. The point of maximum slope of this curve, known as the red edge position (REP), is used, for example, for online control of nitrogen spreading. It has been noted that a difference of only one nanometer may translate to a difference in nitrogen fertilizer requirement of approximately 15 kg/ha. In this work, we performed controlled in silico experiments to investigate the patterns of the red edge displacements resulting from C3 and C4 plants subjected to the same stress conditions. Our findings indicate that specific C3 and C4 REP shifts need to be taken into account in the development of effective monitoring procedures for C3 and C4 crops in order to accurately assess their irrigation and nutrient requirements.
8524-40, Session 4

**Pastureland use planning in Bayan, Mongolia using remote sensing and GIS**

Khishigasuren Nyamsambuu, Kunihiko Yoshino, Univ. of Tsukuba (Japan)

Mongolian pastureland remains as state-owned and do not receive an appropriate regulations and planning to preserve and use them. The semi-arid steppe of Bayan soum, in the central eastern part of Mongolia, was chosen for a field investigation. In recent years, the pastureland in the Bayan soum is facing its livestock feed shortage due to the overgrazing. In order to improve the vegetation biomass growth, a proper pastureland use planning was needed in this area. The main objectives of this study were 1) to monitor and mapping the grassland vegetation biomass 2) to establish the suitable pastureland use planning recommendations for better vegetation productivities.

For the study experiments, vegetation dry biomass by field work and MODIS13Q1 250 m resolution satellite images have been used to determine the relationships between the vegetation biomass and the accumulated NDVI during the vegetation growth period between 2001 and 2011.

The correlation coefficients thresholds between the vegetation biomass and the accumulated NDVI ranged from 0.7 to 0.85. Meaning that, regression equations derived from these relationships were proper in estimation of the vegetation biomass yields. The approach of regression equations that expressed by the accumulated NDVI and the vegetation biomass has given a mapping of the estimation of vegetation biomass productivity. Five different ranking levels of zones, namely, rich, high, normal, low and poor biomass productivities have been identified in the vegetation productivity map. Finally, using the productivity map, the zonal planning to the pastureland use has been recommended to establish the suitable pastureland management.

8524-41, Session 5

**Detection of three-dimensional crustal movements due to the 2011 Tohoku, Japan earthquake from TerraSAR-X intensity images**

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The Tohoku earthquake on March 11, 2011, caused significant crustal movements. According to the GPS Earth Observation Network System (GEONET) operated by Geospatial System Institution (GSI) of Japan, crustal movements with a maximum of 5.3 m in the horizontal direction and a maximum of 1.2 m in the vertical direction were observed over wide areas in the Tohoku (north-western) region of Japan. A method for capturing the two-dimensional (2D) surface movements from pre- and post-event TerraSAR-X (TSX) intensity images has been proposed by the authors [1]. However, it is impossible to detect the three-dimensional (3D) actual deformation from one pair of TSX images. Hence, two pairs of pre- and post-event TSX images taken in descending paths from different incident angles were used to detect 3D crustal movements in this study. First, two sets of 2D movements were detected from two pairs of TSX images. The relationship between the 3D actual deformation and 2D converted movement in TSX was derived according to the observation model of the TSX sensor. Then the 3D movements were calculated from two sets of detected movements in a short time interval. The method was tested on the TSX images covering Sendai area. Compared with the GEONET observation records, the proposed method was found to be able to detect the 3D crustal movement at a subpixel level.


8524-42, Session 5

**Monitoring southwest drought of China using HJ-1A/B and Landsat remote sensing data**

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To monitor southwest drought in China, drought survey models, including Normalized Difference Thermal Index (NDTI), Vegetation Supply Water Index (VSWI) and Temperature Vegetation Dryness Index (TVDI), and two kinds of remote sensing data have been used in this paper.

Firstly, two kinds of remotely sensed data such as TM/ETM+ and HJ-1A/B CCD/IRS images of environment and disaster monitoring and forecast small satellite constellation have been selected from September 2009 to May 2010 in southwest China. Secondly, the selected images have been preprocessed. Different models have been employed to radiometric calibrate the selected images of HJ-1A/B CCD/IRS and TM/ETM+. In order to comprehensive using the selected data to dynamic monitor drought, the three selected images have been re-projected after radiometric calibration. Then, the Normalized Difference vegetation Index (NDVI) images, surface temperature, and cloud detection have been generated. Thirdly, three drought monitoring models such as NDTI, VSWI and TVDI have been used to dynamic monitor the southwest drought occurring from September 2009 to May 2010 in China.

The results showed that different regions of Yunan province and Guizhou province had occurred slight and moderate drought and small regions in northern of Yunan province had occurred heavy drought from November 2009. The wide range heavy droughts had occurred in central and northern of Yunan province, western Guizhou province, and southern Sichuan province in mid of November. In late of January 2010, most regions of Yunan province and Guizhou province had occurred heavy drought and drought had spread to some area of Guangxi province and Hunan province. And when came to early April 2010, there was no decrease of drought range, but the drought degree significantly reduced, and drought began to ease. The southwest drought basically removed in early May 2010. Conclusively, the research results have effectively revealed the occurrence, development and disappearance of the southwest drought in China.
Industrial Technology Research Ctr. (Japan)

The Tohoku Earthquake of 2011 caused extensive damage to the coastal pine forest that protects inland areas from sea breezes. The tsunami uprooted, broke, and tilted the pine trees. In addition, subsequently, the leaves of coastal pine forest turned red and fell down after summer in 2011 in large areas. To detect damage to the coastal forest caused by the Tohoku Earthquake, we analyzed time-series airborne orthophotos and high-resolution satellite images. After the earthquake, many coastal forests were washed away and there is no sign of coastal forest stands in the orthophotos. We compared orthophotos taken before and just after the earthquake by the Japan Geographical Survey Institute. We mapped the damaged forest in Aomori, Iwate, and Miyagi prefectures and classified the damage into three classes: extensive, moderate, and slight damage. We also obtained and high-resolution satellite images (DigitalGlobe, WorldView-2) observed after the summer in 2011. We surveyed the forest damage using field plots. We measured the damage of 50 - 60 trees in a circular plot. The tree damage was classified on a 0 to 10 point scale: a sound tree had 0 damage, while a tree with a completely damaged crown was scored 10. The most crown leaves of a tree scored 7-9 turned red and fell off. The average plots damage were calculated and a linear regression analysis was performed to compare the data for 20 field plots and satellite data. The coefficient of determination was large and we mapped the forest damage using satellite images.

8524-44, Session 5

Detection of damaged buildings using GeoEye-1 imagery and airborne lidar data: a case study on the 2011 Tohoku earthquake

Yoshiyuki Yamamoto, Aichi Institute of Technology (Japan); Tomohito Asaka, Sadayoshi Aoyama, Keishi Iwasita, Katsuteru Kudou, Nihon Univ. (Japan)

GeoEye-1 imagery and airborne lidar (Light Detection and Ranging) data were used to produce damaged building maps caused by the 2011 Tohoku Earthquake and Tsunami on 11 March 2011. The massive disaster caused extensive and severe structural damage along the northeast coast of Japan. The coastal area of Minami-sanriku Town and Ishinomaki City, which is located in Miyagi Prefecture in Japan, was selected as the study area. The area was close to the epicenter of the earthquake and most severely affected by the earthquake and the tsunami. The GeoEye-1 imagery were processed as pan-sharpened multispectral data with 50 cm spatial resolution, and the airborne lidar data were used to generate digital elevation model (DEM) with 2 m and 5 m grids. The examination of selecting the optimum spatial resolution to detect damaged buildings is necessary to analyze these data, because spatial resolutions between these data are different. By setting various spatial resolutions for these data, the detection of damaged buildings were examined through the integration of the pre- and post-earthquake data from GeoEye-1 and lidar data. The rational geometrical theories with various resolution were employed to detect damaged buildings. Our research found that the determination with different spatial resolution produced damaged building maps differently as a result.

8524-45, Session 5

Disaster monitoring by using the Pi-SAR2

Seiho Uratsuaka, Toshihiko Umehara, Tatsuharu Kobayashi, Makoto Satake, Jyunpei Uemoto, Shojihiro Kojima, National Institute of Information and Communications Technology (Japan)

Pi-SAR2 is the airborne Synthetic Aperture Radar (SAR) system which is capable of 30cm resolution with full-polarimetry and cross-track interferometry. The Pi-SAR2 has been developed by NICT aiming at main validation of SAR capabilities for various disaster. In 2012, Pi-SAR2 has observed for the disasters, such as volcanic eruption of Kirishima-yama, earthquake with tsunami in Tohoku area, and land-slides at Nara by heavy rain. In this paper, we show the results of observation to above three events. In each case, we provide the image data of disaster area to appropriate authorities of emergency and citizens through the Web site quickly. These gave contributions to making recovering policies. However, capability of high resolution, polarimetry, and interferometry were not available to quick contribution for these disasters because of the spend time of high-order processing. Also, huge size of data in high-resolution with wide area prevented from quick delivery of the data.

8524-46, Session 5

A framework for diagnosis of environmental health based on remote sensing

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Over the past century, Anomalies of global climate change, deforestation, grassland degradation, soil erosion, desert expansion, species extinction and other ecological and environmental problems become rapidly serious. Harm physical and psychological health of all living things including human. Human survival and development is inseparable from the healthy environment. Facing the worsening environmental problems, scientists all over the world are struggling to find solutions. For physical health problems, we can go to see a doctor and human’s physical health status can be diagnosed using a variety of modern equipment in the hospital. Then, how to assess and diagnose the environmental health of ecosystem?

We purposed a framework to diagnose the environment health of ecosystem at the global or regional scale based on a series of natural ecological factors such as vegetation, water, soil, air and so on. All the selected ecological factors can be acquired and monitored by remote sensing technology. By analyzing the spatial and temporal characteristics and the occurrence and evolution of the driving mechanism of ecosystem, we found out the main factors which affect environmental health, quantitatively defined the parameters’ threshold of environmental safety, set up the objective ecological health assessment index system, and diagnosing of the health of key ecological areas.

The framework for diagnosis of environmental health based on remote sensing can support global and regional scale ecosystem protection, restoration and optimal decision-making management. With the help of environmental health diagnosis, we can effectively prevent ecological damage, reduce the impact of natural disasters, and make a safeguard to human health.

8524-47, Session 5

Semi-automatic recognition and mapping of event-induced landslides by exploiting HR MS satellite images and VHR DEMs in a Bayesian framework

Alessandro C. Mondini, Consiglio Nazionale delle Ricerche (Italy); Kang-tsung Chang, Kainan Univ. (Taiwan); Mauro Rossi, Ivan Marchesini, Fausto Guzzetti, Consiglio Nazionale delle Ricerche (Italy)

Landslides occur every year in many areas of the world. They cause casualties and huge economic losses. Landslide inventories are important to document the extent of the phenomenon in a region, for risk estimation and management, and to study the landscape evolution.

We present a method for semi automatic recognition and mapping of event induced (rainfall, earthquakes) shallow landslides. The method is based on the combination of High Resolution (HR) Optical Multispectral (MS) Satellite images and Very High Resolution (VHR) Digital Elevation Models (DEM) in a Bayesian framework. Mass movement membership probability (prior probability) is estimated from post event satellite images through supervised classification methods. Landslide susceptibility models are used as likelihood in the Bayesian framework. Here, they are obtained through a “data-driven process” by overlapping inventories of the past and morphometric parameters extracted from the DEMs.
The method was tested to map the record-breaking Typhoon Morakot event in 2009, in a portion of the Kaohsiung basin, in Taiwan. It proved successful for the identification of landslides still present in the post-event image; compared to other traditional pixel based approaches, it reduced the “salt and pepper” effect, and it allowed the recognition and separation of landslide source areas and run outs.

5824-48, Session 5

Damage estimation of the great east Japan earthquake by NICT airborne SAR (PI-SAR2)

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On March 11, 2011, a 9.0-magnitude earthquake occurred off the pacific coast of Tohoku area of Japan. Accompanied with the subsequent tsunami, it caused a lot of casualties and damages on buildings, infrastructures and various properties in coastal area. We made urgent observations of the damaged areas by NICT (National Institute of Information and Communications Technology) airborne X-band SAR system (PI-SR2), immediately after the earthquake, on March 12 and 18. In addition, August 25 and October 5 flights were followed to investigate the changes. PI-SAR2 can produce fully polarimetric radar data, with high spatial resolution of 0.3 m. The onboard processor is equipped to obtain SAR images (single-polarization) on the flight, in order for us to distribute the SAR images to whom concerned quickly. The observed areas reached about 500 km in the length in total, with about 10 km in the width. Ground data was also collected on August 25-26 in some selected areas. Fully polarimetric image data were processed to estimate the damages in detail and quantitatively. We have found that the high resolution image data are useful to estimate damaged buildings, flooded areas and amount of debris. Multi-temporal observations are essential to revealed their changes.

5824-68, Session PSWed

Urban waterbody extraction using medium-resolution, multispectral remote sensing image based on knowledge-based decision tree

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Urban water body is essential for urban environment monitoring, heat island and landscape planning research. State-of-art water extraction methods seldom focus on small water body in urban environment. Meanwhile, differentiation between water body and shadow has not been solved efficiently. These two reasons enable urban water extraction to be a challenging task. The balance between resolution and swath width makes medium-resolution multispectral remote sensing imagery to be appropriate for small water body extraction in a large area.

In view of the spectral mixing between water body, building shadow, asphalt road and dense vegetation in urban environment, a knowledge-based decision tree combining spectral and spatial features is constructed to extract urban water body in this paper. The proposed model is composed of four steps:

1. Dark objects in urban environment are extracted based on their low reflectance in SWIR.
2. Dense vegetation and asphalt road are eliminated according to their high reflectance in NIR and R respectively.
3. Differences in spatial density are used to eliminate building shadow.
4. Area threshold is used for supplementary recognition of water body. Dark objects should be concerned in urban water body extraction are proposed and corresponding feature analysis is carried out, and spatial density described by DBSCAN (Density-Based Spatial Clustering of Applications with Noise) is used to discriminate water body from building shadow are two innovations of this paper.

The proposed model is composed of four steps:

1. Dark objects in urban environment are extracted based on their low reflectance in SWIR.
2. Dense vegetation and asphalt road are eliminated according to their high reflectance in NIR and R respectively.
3. Differences in spatial density are used to eliminate building shadow.
4. Area threshold is used for supplementary recognition of water body.

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5824-48, Session 5

Damage estimation of the great east Japan earthquake by NICT airborne SAR (PI-SAR2)

Makoto Satake, Tatsuharu Kobayashi, Jyunpei Uemoto, Yoshikiho Umebara, Urasuaka Seiho, National Institute of Information and Communications Technology (Japan)

On March 11, 2011, a 9.0-magnitude earthquake occurred off the pacific coast of Tohoku area of Japan. Accompanied with the subsequent tsunami, it caused a lot of casualties and damages on buildings, infrastructures and various properties in coastal area. We made urgent observations of the damaged areas by NICT (National Institute of Information and Communications Technology) airborne X-band SAR system (PI-SR2), immediately after the earthquake, on March 12 and 18. In addition, August 25 and October 5 flights were followed to investigate the changes. PI-SAR2 can produce fully polarimetric radar data, with high spatial resolution of 0.3 m. The onboard processor is equipped to obtain SAR images (single-polarization) on the flight, in order for us to distribute the SAR images to whom concerned quickly. The observed areas reached about 500 km in the length in total, with about 10 km in the width. Ground data was also collected on August 25-26 in some selected areas. Fully polarimetric image data were processed to estimate the damages in detail and quantitatively. We have found that the high resolution image data are useful to estimate damaged buildings, flooded areas and amount of debris. Multi-temporal observations are essential to revealed their changes.

5824-68, Session PSWed

Urban waterbody extraction using medium-resolution, multispectral remote sensing image based on knowledge-based decision tree

Jingbo Chen, Chengyi Wang, Dongxu He, Institute of Remote Sensing Applications (China)

Urban water body is essential for urban environment monitoring, heat island and landscape planning research. State-of-art water extraction methods seldom focus on small water body in urban environment. Meanwhile, differentiation between water body and shadow has not been solved efficiently. These two reasons enable urban water extraction to be a challenging task. The balance between resolution and swath width makes medium-resolution multispectral remote sensing imagery to be appropriate for small water body extraction in a large area.

In view of the spectral mixing between water body, building shadow, asphalt road and dense vegetation in urban environment, a knowledge-based decision tree combining spectral and spatial features is constructed to extract urban water body in this paper. The proposed model is composed of four steps:

1. Dark objects in urban environment are extracted based on their low reflectance in SWIR.
2. Dense vegetation and asphalt road are eliminated according to their high reflectance in NIR and R respectively.
3. Differences in spatial density are used to eliminate building shadow.
4. Area threshold is used for supplementary recognition of water body.

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Global land cover classification using annual statistical values
Noriko Soyama, Tenri Univ. (Japan); Kanako Muramatsu, Nara Women’s Univ. (Japan); Motomasa Daigo, Doshisha Univ. (Japan)

Global land cover data sets are required for the study of global environmental changes such as global biogeochemical cycles and climate change, and for the estimation of net primary production. To detect the characteristic of land cover area, phenology of the area is studied using vegetation indices, which are calculated with some bands’ reactivity. In this study, we use the universal pattern decomposition method (UPDM) coefficients and the modified vegetation index based on the UPDM (MVIUPD), which is calculated using the UPDM. The UPDM is suitable for multi-dimensional reactivity values. Four UPDM coefficients and the MVIUPD values are useful for determining land cover conditions. To simplify the algorithm of land cover classification, we use annual statistical values, e.g., maximum, minimum, average or standard deviation, correlation coefficient values of MVIUPD and UPDM coefficients. This paper describes the simple algorithm for global land cover classification, which has 16 land cover classes denoted based on International Geosphere-Biosphere Programme (IGBP). Primary source data of this algorithm are 46 periods of 8-day composite 7-band 500-m MODIS data of 2007. The natural global land cover map was roughly similar to the image of the MOD12Q1.

Impact of land use/land cover change on land surface temperature to estimate urban heat islands in Hino City
Nang Mya Mya Nwe, Tokyo Univ. of Marine Science and Technology (Japan)

Recently, there is an increasing demand for information on actual land use/land cover (LU/LC) from planning, administration and scientific institutions. Remotely sensed thermal infrared (TIR) data have been used widely to retrieve land surface temperature (LST) which is an important parameter in the studies of urban heat island (UHI), mainly caused by modification of the land surface by urban development. The objectives of this study are to detect LU/LC change and to analyze the impacts of change detection on the LST using ASTER thermal bands between June to September, 2012 in order to estimate urban heat islands. The study area is Hino City, Tokyo, which combines different land use/land cover regions. TR-5i Series data loggers were set up in six places of Hino City collecting temperatures data as well as related positioning every 30 minutes between June to September, 2012. The single channel algorithm will be used to calculate both day and night times LST from ASTER thermal bands at the same period. After the differences between the measured and calculated temperatures are adjusted, the effect of land use/land cover on land temperature will be analyzed by overlaying the LST map and LU/LC map with ArcGIS tools. From this investigation, it is considered helpful to the communities taking the action of the urban heat islands mitigation which affect energy use, air quality and human health though the effort to make the LU/LC map by visual interpretation is still very high and cannot keep up with the development pace.

Microwave monitoring of the soil moisture
Ferdenant A. Mkrtchyan, Institute of Radio Engineering and Electronics (Russian Federation)

Interrelations between the characteristics of the microwave emission field of moistened soil and of the soil liquid water content, soil density, temperature and mineralization level of liquid water are the properties studied both theoretically and by field measurements. Both research and field studies show that microwave radiometric measurements permit estimates of 7 to 10 moisture levels in the top 0.1 to 1.0 wavelengths of soil and 3 to 7 grades of the subsurface water level between 0 and 1.5-3.5 m. The soil moisture is divided on the solidly-united, loosely-united, and free one. United moisture is the water adsorbing by ground particles surface and having the form of film with the thickness equal no more of 6 to 8 molecular layers. The volume of united moisture in the soil layer is determined by the soil type and is fluctuated in the wide interval from 2-3 per cent for sandy soil to 30-40 per cent for clay and loess soils. United water is unattainable for the plants and do not influence on the salt regime of soil. That is why the monitoring system is to realize that kind of moisture classification in the soil. The soil moisture is expressed in per cent of dry soil weight. The radiation models of the soil moistering for different types, taking into consideration of soil density, its temperature and salinity, were studied in the details. The data required for solution of the moisture problem can be obtained from the values of brightness temperature contrasts, degree of polarization and spectral characteristics at centimetre and decimetre wavelengths. Wavelengths 2.25, 18 and 30 cm proved to be the most informative to solve this task. The microwave radiation model describing the land cover emitively under the conditions of heterogeneous moisture is primary based on the existence of vertical heterogeneity in the dielectric permeability coefficient. The existence of knowledge base that kind and application of GIMS technology allow to solve the task of water content, Wa(z), diagnostics in the soil layer.
8524-80, Session PSWed

Retrieval of land surface temperature by cross-calibrated SVISSLR thermal infrared data onboard China geostationary satellite

Xiaoying Ouyang, Institute of Remote Sensing Applications (China); Li Jia, Alterra, Wageningen University and Research Centre (Netherlands); and Institute of Remote Sensing Applications (China)

A practical algorithm is developed to retrieve spatial-temporal land surface temperature (LST) using the Stretched Visible and Infrared Spin Scan Radiometer (SVISSR) time series data from China Feng-Yun 2C (FY-2C) geostationary satellite. A cross-calibration method and a general split-window algorithm for FY-2C/SVISSR data are developed. An automatic procedure is developed to implement the proposed methods for LST retrieval from FY-2C/SVISSR. Results from cross-calibration show that a good linear relationship between the TOA brightness temperatures from FY-2C/SVISSR and that from MODIS was found with correlation coefficients as 0.95 notwithstanding the differences of spectral response function between the two sensors. Comparisons among in-situ LST measurements, AATSR LST product and FY-2C/SVISSR derived LST are done. The results show that the SVISSR derived LST can be evaluated with aggregated AATSR derived LST, as well as the in-situ measurements. Validation is then done by comparing with the in-situ LST measurements at two experimental sites in the Heihe River basin-Arou and Yingke. In the Arou site, the Root Mean Square Error (RMSE) is 4.04K and the correlation coefficient R is 0.95. In the Yingke site, the RMSE is 3.02K and the R is 0.85. Limitations and uncertainties in retrieving LST using the algorithms for FY-2C geostationary satellite are also discussed.

8524-81, Session PSWed

Radiometric calibration method of the general purpose digital camera and its application for the vegetation monitoring

Kenta Tokunaga, Masao Moriyama, Nagasaki Univ. (Japan)

This paper shows a way to use a general digital camera as a multi-spectral camera. The purposes of this development are cost reduction and simplified processing for the spectroscopic measurement. The camera which can save the image as RAW format is used in this study.

The authors estimated RGB-sensitivities and RGB-responses of the camera based on the discrete expression of the RGB-response, approximation of the RGB-sensitivity and exposure relationship and the simultaneous estimation scheme of the sensitivity and the response. So authors have been able to compute incident RGB-radiance from a RGB pixel value with the 8bit accuracy. Also in this paper, authors developed the spectral response dividing method with the long-pass filter.

First, the radiance(E) correspond to the normal response of the camera is taken.

Second, the transmitted radiance(E1) with the long-pass filter is taken. The transmitted radiance(E1) can be computed as the weighted integration of the RGB-response, the long-pass filter transmittance and the incident spectral radiance. Also the blocked radiance can be computed as the difference between the normal(E) and transmitted(E1) radiance.

As the primary application of this method, the radiance based NDVI and the red edge information can be estimated. These image are made from the image which is taken by the digital camera which has the sensitivity in the near infrared spectrum. These images are validated by the simultaneously measured radiance by the spectroradiometer.

8524-82, Session PSWed

Satellite-based fire detection algorithm for GCOM-C1/SGLI

Takashi Miura, Masao Moriyama, Nagasaki Univ. (Japan)

The sensor named SGLI onboard JAXA’s new earth observation satellite GCOM-C1 will produce many kinds of environmental products. One of them, the fire detection product will be produced. Unfortunately, SGLI does not have 4 micrometer spectrum observation channel which plays an important role of the fire detection for the previous sensor such as MODIS.

SGLI has 2 observation channels in the SWIR windows spectrum 1.6 and 2.2 micrometer. From the high temperature target, the observed radiance at these channels are getting larger because the thermal emission becomes significant.

To detect the fire from the radiance at the SWIR spectrum channels, the thresholding technique is developed by using the high spatial resolution dataset such as TM, ETM+ and ASTER. To reduce the false alarm from the bright target near infrared spectrum radiance and the thermal infrared spectrum radiance. The near infrared radiance is used to detect the high reflectivity pixel where the Fresnel reflection occurred. The thermal infrared radiance used to remove the undetected cloud, ice or snow.

The comparison result between MODIS fire product and the proposed method output shows the lower detectivity but the fewer false alarm. The result shows the proposed method shows the reliability of the fire detection.

Also the fire temperature and the fire proportion algorithm is developed.

This problem is a sort of mixel decomposition, to get the stable solution, the stepwise estimation of the fire proportion using the relationship between the fire proportion and the reflectance difference between 1.6 and 2.2 micrometer and the fire temperature estimation using the non-linear least square method.

8524-83, Session PSWed

Exploring optimal design of look-up table for PROSAIL model inversion with multi-angle MODIS data

Wei He, Hua Yang, Jingjing Pan, Peipei Xu, Beijing Normal Univ. (China)

Physical remote sensing model inversion based on look-up table (LUT) technique is promising for its good precision, high efficiency and easily-realization. However, the LUT is not always well designed, as lacking a thorough investigation of its mechanism in responding to different designs, for instance, the way the parameter space is sampled. To solving this problem, several LUT design experiments are performed and their effects on inversion results are analyzed. Using MODIS sensor’s geometrical observation angles, 1000 groups of randomly generated parameters of PROSAIL model are taken to simulate multi-angle observations. The correlation coefficient (R2) and root mean square error (RMSE) of input LAI’s for simulation and inverted LAI’s were calculated. The R2 is higher and the RMSE is lower, the inversion result is better. The experimental results show that, sampling amount is a key factor, and the RMSE is lower than 0.1 when the sampling amount reaches 100,000; Taking the median of the selected solutions as the final solution is better than the mean or the “best” whose cost function value is the least; Different parameter distributions have a certain impact on the inversion results, and the results get better when using a normal distribution; Selecting 50 solutions as the best is better than 100 or 200 when the sampling amount is within 250,000. Finally, we inverted and validated winter wheat LAI of one research area in Xinxiang City, Henan province, with MODIS daily reflectance data, and the result shows it works well.

8524-84, Session PSWed

Estimating the gross primary production capacity from global observation satellite

Kanako Muramatsu, Juthasinee Thanypaaneedkul, Nara Women’s Univ. (Japan); Shinobu Furumi, Narasaho College (Japan); Noriko Soyama, Tenri University (Japan); Motomasa Daigo, Doshisha University (Japan)

Estimation of Gross Primary Production with high accuracy is important for understanding the carbon cycle. For estimating gross primary production, photosynthesis process was considered into
two parts. One is the capacity and another is the reduction which is influenced by environmental conditions such as weather conditions of vapor pressure difference and soil moisture. The capacity estimation part is reported in this conference. For a leaf, it is well known that the photosynthesis capacity is mainly depend on amount of chlorophyll and enzyme. Chlorophyll contents reflect the color of a leaf. Since we focus on the chlorophyll contents for estimating the capacity of the gross primary production. The index of the ratio of green band and near infrared has been reported that it was linear relationship with chlorophyll contents of a leaf, and with the maximum photosynthesis at light saturation of light response curve with less stress conditions using the flux data. The index was only using the spectral data being available of global observing satellite. Using the index and empirical relationship, the light response curve with less stress is expected to be estimate. In this study, firstly, the global distribution of the index was studied. The regions of high index value in winter time were correspond to tropical rainforest. Next, the capacity of gross primary production was estimated using the light response curve using the index. The GPP capacity of the almost all regions was higher than MODIS GPP. For the tropical rain forest regions, the GPP capacity value was similar with MODIS GPP.

8524-85, Session PSWed
Assimilation of HJ-1 NDVI data into a parameterized vegetation NDVI dynamics models
Jinling Song, Beijing Normal Univ. (China)
The Normalized Difference Vegetation Index (NDVI) time series can represent vegetation changes on land surfaces both in time and space. In this paper, the main object is to study on the generation of the high spatial temporal resolution NDVI product by fusing HJ-1 reflectance data and MODIS NBAR product in Heihe river basin. MODIS 8-day 1-km nadir BRDF-adjusted reflectance (NBAR, MOD43B4) from year 2004 to 2009 and the HJ-1 30-m surface reflectance in 2009. There also used the Quality data MOD43B2, as well as the MODIS 1-km land cover (MOD12Q1) and HJ-1 30-m land cover map. We use the field measured data in Yike and Linze, Heihe river basin in Gansu province, China. Based on the HJ-1 NDVI data, the main object of this paper is to generate the high spatial and high temporal resolution NDVI product. One method is proposed to get high spatial and temporal resolution NDVI product by fusing MODIS NBAR product and HJ-1 NDVI data. In this method, the LULC data is used to register with MODIS data, then the percentage of classes of PFT classification in the MODIS pixel can be calculated. And the multi-year mean MODIS NBAR product of pure pixels for each vegetation types are used to built the parameterized NDVI dynamic models. And the HJ-1 NDVI data is used to adjust this curve of NDVI dynamic models. And we validate NDVI with high spatial and high temporal resolution using the measured data, and the result is good and can meet our study needs.

8524-86, Session PSWed
Relation between vegetation activity and local climate over East Asia using GIMMS NDVI and climate data
Ara Cho, Myoung-Seok Suh, Seung-Hwan Kwak, Kongju National Univ. (Korea, Republic of)
In this study, relation between remotely sensed NDVI (Normalized Difference Vegetation Index) and local climate over East Asian region were examined using 25 years (1982-2006) GIMMS (Global Inventory Modeling and Mapping Study) NDVI and CRU TS 3.0 climate data. The spatial resolution and temporal frequency of GIMMS NDVI are 8x8km2 and 15 days, respectively. The same period of CRU TS 3.0 climate dataset also obtained. The temporal frequency and spatial resolution of the data are monthly and 0.5°x0.5°, respectively. To improve the quality of original GIMMS NDVI dataset, we developed and performed a detection and correction method of noisy pixels based on the spatio-temporal continuity of NDVI. In order to synchronize the spatial resolution of two datasets, the bi-weekly GIMMS NDVI data are averaged to match with the same month CRU TS data and interpolated into 8x8km2 grid using the bilinear interpolation method. The vegetation activity at high latitude region is more closely related with temperature than lower latitude. As a result of global warming, the growing period of vegetation has been extended, and the earlier beginning and delayed ending of vegetation activity in most of high latitude region. The increasing trends are more significant during spring than fall. Also the positive correlation between NDVI and air temperature is higher during spring than fall as in the trends. One month lagged precipitation sows a higher correlation with the GIMMS NDVI than concurrent month, especially at mid-latitude area, where the vegetation activity is mainly controlled by soil moisture. NDVI over dry area such as desert, semi-desert and short grass region is highly linked with precipitation.

8524-87, Session PSWed
Spatial Distribution of Croftton Weeds in Southwest China with MODIS NDVI of Long Time Series
Li Wang, Suhong Liu, Beijing Normal Univ. (China); Lizhao Wang, Xiaojia Liang, Beijing Normal University (China)
Eupatorium adenophorum, which was introduced into the south east of China in 1940s via the border between China and Burma, has now a serious bad effect on the biology diversity and the living environment in those regions, including Yunnan, Sichuan, Guizhou, Guangxi, Tibet, Chongqing, Hubei and Taiwan. To help handle this situation effectively, there has been many researches on the utilizing the remote sensing images to monitor the spread of eupatorium adenophorum. However, it is difficult for these researches to monitor it well because eupatorium adenophorum is confused and mixed up among a great deal number of vegetation.
For our research, the processing includes these main steps as follows:
(1) Extract the spectral feature values of eupatorium adenophorum at the different growth stages through a long time work in the sampling regions.
(2) Compare the NDVI of eupatorium adenophorum, grassland, woodland, crops, water bodies, residential areas in the typical sampling regions by using the temporal series of remote sensing images.
(3) Classify the remote sensing images of the research regions according to the different features of NDVI curves based on the temporal series.
(4) To gain the precision of classification, examine whether the classification results are matched to the actual types of objects or not.
To sum up, we gained a relatively accurate classification results and made a high-accuracy distribution map of eupatorium adenophorum. Thus, our research is helpful to monitor the spread of eupatorium adenophorum.

8524-89, Session PSWed
The study on the method of evaluating development status of island based on multiscale vegetation indices’ analysis
LI H. Li, The Second Institute of Oceanography, SOA (China)
In this paper, to meet the demands of the dynamic evaluation of the development status of island, we did some research on the development status evaluation of island with the large scale, dynamic remote sensing method, based on the sharp sensitivity of vegetation to human activities, and vegetation index’s ecological meanings. Firstly, we analyzed different disciplines of different land use types’ vegetation indices under different scales. Then we proposed a development status evaluation model of island based on multi-scale vegetation indices. In the end, we evaluated the development status of the Daxie Island with the proposed new model and SPOT-5 image of Daxie Island in 2005, and got the following results:
(1) Through another point of view, we got the development status of every single pixel of the Daxie Island.
(2) Based on calculation results of every single pixel, we got different development contours having different development value, and then analyzed the spatial differences of development status of Daxie Island in 2005.
(3) By comparing current land development situation and high resolution remote sensing images with our results, we found that the results were reasonable, objective, and in accord with the reality, and the proposed new model was an effective method for evaluating the development status of island.

(4) Our results showed that the proposed new model can be used to fast, dynamic, and large scale development status evaluation of island.

8524-106, Session PSWed
Temporal and spatial variation of MODIS vegetation index for Nantong city
Zhenhua Chao, Nantong Univ. (China); Xiaohong Gao, Qinghai Normal Univ. (China)

The vegetation change is mainly affected by natural factor such as climate and human factor such as urbanization. To a certain degree, urbanization is the main driving force for eastern China. Vegetation index with rich vegetation structure and functional information is an important parameter of surface vegetation characteristics. Nantong is located in eastern Jiangsu province, China. The south of the city are Shanghai and Suzhou city across Yangtze river, China’s most economically developed area. With the opening of Su-Tong Bridge across the Yangtze River in May 2008, the pattern of Nantong city had changed greatly.

To investigate the urbanization effect on Nantong city, the temporal and spatial variation of normalized difference vegetation index (NDVI) products from MODIS between 2004 and 2008 was analyzed. The data were acquired in mid-September that most days are clear in the region. The composite MODIS-NDVI products at 16 days temporal resolution were used. The spatial resolution is 250 meters. The landscape fragmentation in 2004 was less than in 2008. After the opening of Su-Tong bridge, the degree of landscape fragmentation increases. On the basis of the difference between the data, the result showed that the NDVI reduced from 2004. The NDVI in the northwest of Nantong city decreased drastically and due to the open of Nantong railway station in 2007. More roads to the station dredged and real estate opened accordingly. The NDVI in city center surrounded by Haohe river increased for the rational planning and the construction of public green space. With the use of a new port near Langshan railway station in 2007. More roads to the station dredged and real estate opened accordingly. The NDVI in city center surrounded by Haohe river increased for the rational planning and the construction of public green space. With the use of a new port near Langshan.

Rational planning needs to be paid more attention to the sustainable urban development.

8524-107, Session PSWed
Multispectral lidar for vegetation reflectance and fluorescence detection
Song Shalei, Wuhan Institute of Physics and Mathematics (China)

Remote sensing offers the unique possibility to derive explicit information on vegetation status at local, regional or landscape scale. Reflectance signals alone, however, cannot quantify photosynthetic activity and dynamics of vegetation accurately. Chlorophyll fluorescence analyses are among the most powerful techniques to non-destructively quantify photosynthetic efficiency and non-photosynthetic energy dissipation in photosynthetic active organisms under laboratory and field conditions. At high-resolution (very high resolution, VHR) satellite imagery, it is difficult to identify the landslide areas using only backscatter change pattern in pre-disaster and post-disaster COSMO-SkyMed imageries. Thus, the authors adopted correlation analysis between pre-disaster and post-disaster COSMO-SkyMed imageries. The moving window was selected for the correlation coefficient calculation. Low value of the correlation coefficient reflects change between pre-event and post-event imageries. The analysis is effective for the identification of landslides using SAR data. The identified landslide areas were compared with the area identified by EROS-B high resolution optical imagery.

In addition, we have developed 3D viewing system for geospatial visualizing of the damaged area using these satellite image data with digital elevation model. The 3D viewing system has the performance of geographic measurement with respect to elevation height, area and volume calculation, and cross section drawing including landscape viewing and image layer construction using a mobile personal computer with interactive operation. As the result, it was verified that a quick response for the disaster identification at the initial stage could be performed using optical and SAR very high resolution satellite data with 3D viewing system.

8524-90, Session PSWed
Landslide detection using very high-resolution satellite imageries
Yuzo Suga, Hiroshima Institute of Technology (Japan); Tomohisa Konishti, Nihon CADIC Co., Ltd. (Japan)

The heavy rain induced by the 12th typhoon caused landslide disaster at Kii Peninsula in the middle part of Japan. We propose a quick response method for landslide disaster mapping using very high resolution (VHR) satellite imageries. Especially, Synthetic Aperture Radar (SAR) is effective because it has all weather and day/night imaging capabilities. In this study, multi-temporal COSMO-SkyMed imageries were used to identify the landslide areas. The moving window was selected for the correlation coefficient calculation. Low value of the correlation coefficient reflects change between pre-event and post-event imageries. The analysis is effective for the identification of landslides using SAR data. The identified landslide areas were compared with the area identified by EROS-B high resolution optical imagery.

8524-91, Session PSWed
Analysis of road damage after a large-scale earthquake using satellite images
Keishi Yamaguchi, Hitoshi Saji, Shizuoka Univ. (Japan)

We propose a method of using satellite images for analysis of road damage after a large-scale earthquake accompanied by tsunami disaster. Remote sensing using satellite images can collect wide area information at a time and obtain information for activities for relief assistance quickly and correctly after a large-scale disaster, such as the Great East Japan Earthquake in Japan on March 11, 2011. Although a large number of studies have been focused on the extraction of damaged buildings and the rubble on the roads, little is made on the extraction of flooded areas on the roads by tsunami. After the Great East Japan Earthquake, we have needed a system of analyzing the roads damaged by the earthquake and the tsunami. In this paper, we extract the damaged areas on the roads in detail and help to support activities for relief assistance after the disaster. In our method, we first apply the region extraction method and the edge extraction method to satellite images, and we extract rubble areas and flooded areas. Then we analyze these areas on the road sections and search the passable roads using a digital map. In the experiments, our method extracted 84% of rubble areas and 83% of flooded areas on the roads and found most of the passable roads. Our proposed method enables the analysis of detailed information of damaged roads after a large-scale earthquake.
8524-92, Session PSWed

Study on the tie point selection for DEM extraction from stereo PRISM images

Yoshiyuki Kawata, Akihiro Funatsu, Satoshi Yoshii, Kazuya Takemata, Kanazawa Institute of Technology (Japan)

The accuracy of DEM extraction was analyzed from the view of tie point on the stereo PRISM images. We found that the DEM extraction with a better accuracy was possible when using a single tie point with higher image correlation in the automatic tie point collection method. The selection of the tie points on the stereo images were made using the DLT model characterizing the relationship between two dimensional image coordinate system and three dimensional object coordinate system, after the initial RPC transformation of triangular points. We also examined the dependence of the accuracy of DEM on the altitude of tie point in the manual tie point collection method.

8524-93, Session PSWed

Assessing remote topographic datasets: comparing ASTER GDEM, SRTM and the role of ICESat/GLAS transect data with survey control points for floodplain modelling

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Topographic data plays a critical role in water resources modeling. Raster-based DEMs are the basis for deriving topographic attributes used in hydraulic and hydrologic modeling such as slope, stream network, basins boundary and area. Accurate models of floodplain topography are essential for having accurate output of hydrologic models. We compared the ICESat GLA14 elevation products and corresponding SRTM and ASTER GDEM at the location of 5000 ground survey control points from a 9x9degree (900x1000 km) area in Queensland, Australia. This area contains large and remote river basins, where these datasets provide an invaluable resource from which river floodplain inundation can be measured and modelled. We also used the ICESat satellite altimetry points to conduct further assessment of the ASTER GDEM and SRTM DEMs more widely over the study area. Our ICESat-control point, ICESat-DDEM and DEM-DDEM analysis shows that SRTM DEMs are more suited than ASTER GDEM data for large scale hydrologic studies in our basins, even with the lower spatial resolution. The ASTER GDEM shows inland water noises and other noises like straight lines which are caused by the methods that are used to produce them that affect replication of hydrological processes. Our study also demonstrated a potential for using survey datum to provide a reliable assessment of relative and absolute ground topographic accuracies which allowed us to correct absolute elevation errors through datum adjustment by analyzing the difference of the SRTM DEM and ICESat elevations, with corrections made to the DEM for hydrological modeling applications. The ICESat data also provides a higher-accuracy topographic dataset at locations of the transects that allowed us to validate floodplain models derived from SRTM.

8524-94, Session PSWed

GIS-based data assimilation of a numerical model for hazard assessment

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THE Earth as we see it today is in a state of continuous change. To accustom with these ever so continuous changes a study of the same is very necessary. In this light hazard assessment has gained considerable significance.

But, the generic term, Landslide Hazard does not specifically signify the landslide deposit or the movement neither of material down slope nor to the movement of an existing landslide mass. Owing to the wide vistas of landslide phenomena which are both complex and variable a single definition is unsuitable. Emphasis has been given here to the dynamics of landslide that determines hazard under different scenarios. Dynamic models (here MassMov2D) have the merits of predicting the single causative factors and being related to deterministic or physically based models have some co-relations between the inputs and the output.

Modelling and parameterization apart the real challenge lies in the efficient analyses and assimilation of the unmanageably large amount of output resulting from the model runs. IDL programming algorithms have elucidated the hurdles of making maps and thereby assimilation of large data. In this study algorithms in IDL have been developed to assimilate the results of model simulation at various steps from calibration to the derivation of the hazard maps. Application of these algorithms has not only increased the efficiency of arriving at the result (landslide runout maps) but helped in reducing redundancy of data and increasing validation of results.

8524-95, Session PSWed

A study of BRDF over Tokyo for the spaceborne measurements of atmospheric trace gases

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We have studied the Bidirectional Reflectance Distribution Function (BRDF) over Tokyo using satellite data in order to evaluate the effect of the surface albedo on air-pollution monitoring from space. When we observe trace gases in the atmosphere utilizing the absorption of solar light (in the UV, visible and near infrared wavelength domains), we need to know in advance the surface albedo, which changes depending on the geometry between the sun, a satellite, and a target point on the ground: the directions of solar light incoming into/outgoing from the surface. The dependency of the surface albedo on the direction of the light is the so-called BRDF. In past studies on the retrievals of trace gas concentrations, often a Lambertian reflectance (i.e., no dependence of the directions) was assumed for simplicity. However, a recent study (Zhou et al [2010]) showed that the dependence of surface albedo on the line-of-sight angle affects the tropospheric gas measurements. Several on-going projects of spaceborne air-pollution monitoring are planning to use a geostationary or non-sun-synchronous orbit to monitor the diurnal variations of pollutants. In those orbits, the geometry would be variable, and the behaviour of the BRDF over the regions of interest should be figured out closely. In the present study, we use the Ross-Thick-LiSparseReciprocal model with MODIS data to retrieve BRDF information, and we focus on the Tokyo area, Japan, which is one of the most polluted areas in Asia. We developed an empirical model of BRDF over Tokyo for the evaluation of atmospheric measurements.

8524-96, Session PSWed

A MATLAB Toolbox for EnviSAT InSAR Data Processing, Visualization, and Analysis

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Interferometric Synthetic Aperture Radar (InSAR) is an emerging technology with increasing applications in environment monitoring and 3-D ground survey. Advanced synthetic aperture radar (ASAR) carried out by EnviSAR can provide data for interferometry and high precision 3-D digital elevation model (DEM) ground mapping.

The publicly available Next ESA SAR Toolbox (NETS) software developed by Array Systems Computing Inc. under European Space Agency (ESA) Contract is user friendly software for reading, post-processing, analyzing and visualizing the large archive of data from ESA SAR missions. However, the NETS software has limited capabilities in data processing, visualization, and analysis.

In this project, a user-friendly Matlab Toolbox is developed under the very popular MATLAB software environment to enhance InSAR and DEM applications. The developed Matlab tools can provide high quality and flexible data processing, visualization and analyzing
functions by tapping on Matlab's rich and powerful mathematics and graphics tools. The Matlab Toolbox includes binary data readers, a number of 2-D or 3-D visualization tools with flexible choice of color schemes, handy geographical distance calculator, and necessary data extraction for detailed analysis of interested zoom-in areas. Case studies are presented with enhanced InSAR and DEM processing, visualization, and analysis examples. The presented examples with two sets of recent Envisat ASAR composite image data covering Singapore are part of a satellite remote sensing education project in collaboration with ESA.

8524-97, Session PSWed

Extraction of road traffic information using satellite images and a three-dimensional digital map
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Analysis of traffic information is one of the applications of remote sensing. Several studies have been reported for vehicle extraction from satellite images or aerial images by using image processing methods. The analysis of these images is not influenced by the ground damage and can obtain a lot of information over a wide area. In such studies, the shadow areas casted by buildings are the cause of errors in extracting vehicles in urban areas. This is because the shadow areas are dark and the positions of vehicles in the areas are unclear. In this paper, we propose a method of extracting shadow areas casted by buildings using three-dimensional digital map data of buildings and extracting vehicles in the areas using image processing methods. The conventional method of extracting shadow areas uses the image intensity, however, this method has the problem that objects having low intensity are mis-extracted. Our method solves this problem by estimating the position and shape of shadow areas by using three-dimensional digital map data and metadata of a satellite image. In vehicle extraction, we use edge detection method for detecting the outlines of vehicles. The detection of the vehicle edges is difficult, since the intensities of vehicle edges are different in the sunny areas and in the shadow areas. However, by extracting shadow areas using the map data in advance and computing the threshold of the edge detection dynamically, our method can detect the vehicle edges and obtain the vehicle positions correctly. We developed relevant software on the computer, and we analyzed actual images to evaluate the effectiveness of our method.

8524-98, Session PSWed

Relationship between DMSP/OLS nighttime light and CO2 emission from electric power plant
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The Defense Meteorological Satellite Program (DMSP)/Operational Linescan System (OLS) has a unique capability for monitoring nighttime light present at the Earth's surface which includes human settlements (stable light), clouds affected by moonlight, forest fires, fishing boats and gas flares. Several studies have already clarified that stable light is one of the most important components for monitoring electric power consumption, economic activity and carbon dioxide emission. In this study, we estimate the carbon dioxide emission from the electric power plant using DMSP/OLS stable light image in 1999. First, we generate the stable light image from daily DMSP nighttime imagery in 1999. Then, develop a saturated light correction method for the DMSP/OLS stable light image using the nighttime radiance calibration image of DMSP/OLS. Almost all DMSP/OLS nighttime stable light is emitted from the illumination of human settlements, suggesting a clear correlation between the emission of stable light and electric power consumption. However, electric power consumption is transported from electric power plant, which emits the carbon dioxide in thermal power generation. Thus, we examine the correlation between cumulative DNs of corrected stable light image, amount of electric power generation, electric power consumption from lighting and total amount of electric power consumption in each electric power consumption area of Japan. Finally, a regression analysis (R2=0.858) was performed between cumulative DNs of the stable light image and carbon dioxide from electric power plant. The new method proves therefore to be very efficient for estimating CO2 emission from electric power plant using stable light image.

8524-99, Session PSWed

Landsat-imagery-based water turbidity monitoring in lake Paldang, Korea
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Landsat TM (thematic mapper) and ETM+ (enhanced thematic mapper plus) imagery, respectively acquired in 2001, 2006 and 2007, were utilized to estimate turbidity in Lake Paldang. Field measurement was collected in-situ on a 10-day basis using multi water quality sensor (DS5, Hydrolab) at 12 fixed points in Lake Paldang. Our analysis considered the interval 10-day (to match the available data from Landsat imagery) and only data from the 12 points that met the following criteria: (1) match with a cloud-free Landsat imagery of the similar dates; (2) the pixel covering the point or the one next to it were mostly covered with land, bight or other sediment except water; and (3) had a water depth ≥ 2.4 m to avoid bottom reflectance contamination.

The result of this study is that when we carried out PCA using Landsat imagery, turbidity had contributed at PC 2 which was similar to the in-situ data. A correlation formula (turbidity = 0.3169 xPC2 -21.477, R2 = 0.6319, N = 30) between the in-situ data and PC2. And we can now use formula to map the turbidity distribution from the synchronously acquired Landsat imagery, and continue the discussion on the inverse turbidity results of the Landsat imagery.

Because results from this type of study vary with season and time of day, it is necessary to monitor continuously in-situ data as well as radiance feature of reflectance in order to determine accurately the environmental factors of water quality.

8524-100, Session PSWed

Methane analysis using SCIAMACHY data in permafrost area of China
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Gas hydrates are ice-like crystalline solids composed of water and gas, which widespread in permafrost regions and beneath the sea in sediments of outer continental margins. It is a new kind of potential and clean energy resource, and the dissociation of hydrate also play a great role in climate change due to their strong greenhouse effect. In this research, Monthly methane concentration of Muli area from 2003 to 2008 is firstly analyzed, where natural gas hydrate sample was detected in 2008. It is found that monthly methane concentration of this area in December is obviously higher than that of surrounding area. And before 2006, the monthly methane concentration of August in the area is slightly higher than that of other months, which is the same with the distribution of the whole country, however, the rule changes after that. The monthly methane concentration of winter in Muli area becomes the same high with that of summer. Compared with the timely earthquake data of this area, it is known that monthly methane concentration in March 2007 abnormal increased for a little earthquake of magnitude 4.2 happened February 23rd, 2007. Based on the analysis results of Muli area, monthly methane concentration in permafrost area of China from 2003 to 2008 is analyzed to monitor the possible methane seepages of potential gas hydrate area.

8524-101, Session PSWed

A study of fraction of absorbed photosynthetically active radiation characteristics based on SAIL model simulation
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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. It makes FPAR different. So this difference between direct FPAR and diffuse FPAR must be determined to decide whether it should be considered into the FPAR inversion model. In this study, the sail model was modified which could output direct FPAR and diffuse FPAR. Then with the characterized input parameters such as solar zenith angle, visibility and LAI, the direct FPAR and diffuse FPAR would be change. From the simulation analyses, we could see that direct and diffuse FPAR are different with the changes of environment variables. So when modeling of FPAR, the diffuse part cannot be ignored. Direct FPAR and diffuse FPAR must be modeled respectively. This is the next issue worth studying.

8524-102, Session PSWed
Distribution of solar radiation including slope effect in South Korea
Shin Chul Baek, Sang Il Na, Jin-Ki Pack, Jong-Hwa Park, Chungbuk National Univ. (Korea, Republic of)

Extracted slope from the DEM in South Korea include range between 0° to 18° and most of the land is mountainous. According to the slope, solar radiation characteristic show to have high value in spring season(April) relatively other season. Because, summer season interrupt to reach direct solar radiation, cause is unstable atmospheric and cloud. The distributions of monthly accumulated solar radiation indicated that differences caused by the topography effect are more important in winter than in other season because of the dependency on the solar altitude angle and duration of sunshine. Also, Result of Klein and Thielacker method is confirmed to overestimate monthly average 1.37MJ/(m²/day) than solar radiation weather station measurement values. Solar radiation of slope error value will need continuous research and correction through both field survey and topography factor.

8524-103, Session PSWed
Hyerspectral land surface remote sensing using a VNIR airborne imaging spectrometer
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Hyerspectral imaging or imaging spectroscopy with hundreds of spectral channels in visible and near infrared region (VNIR) is one of the perspective directions of airborne monitoring to recognize land surface objects. The characteristic feature of hyperspectral systems is maintained to be in their ability increasing the information content of registered data as compared with the commonly used multispectral systems. Produced for the enhanced spectral characterization, the hyperspectral systems meanwhile may have redundant channels for particular scenes due to the correlation between data in the relevant channels. A necessity emerges to reduce this redundancy by computational treatments. We have developed during the last several years an apparatus and programmatic system of hyperspectral airborne remote sensing imaging processing for selected sites of the land surface. Produced in Russia, the original prismatic VNIR hyperspectrometer operates in up to 287 spectral channels. Technical characterization is made of the relevant equipment. Some results of studying the linearity of calibration and noise characteristics are given. Thematic processing consists in the classification of land surface objects and the retrieval of parameters for the forested environments on a pixel-by-pixel basis. The used pattern recognition techniques are based on the Bayesian approach and include the subsequent stages of spectral and spatial analysis. The stability of the classification approach is shown from the object recognition results obtained from some overlapping hyperspectral images revealed. New possibility of validation of the airborne hyperspectral data using the retrieval of the projective characteristics of the forest canopy from ground-based photos is discussed.

8524-104, Session PSWed
Forest biomass estimation algorithms for the earth observation satellite optical sensor using multi-angle observation data
Koji Kajiwara, Chiba Univ. (Japan); Yusaku Ono, Japan Aerospace Exploration Agency (Japan); Yoshiaki Honda, Chiba Univ. (Japan)

Japan Aerospace Exploration Agency (JAXA) is going to launch new Earth observation satellite GCOM-C1 in FY 2014. The core sensor of GCOM-C1, Second Generation Global Imager (SGLI) has a set of along track slant viewing Visible and Near Infrared Radiometer (VNIR). 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, shadow index, etc. In this paper, we introduce the ground observation method developed by using Unmanned Aerial Vehicle (UAV) in order to contribute the algorithm development and its validation. Mainly, multi-angular spectral observation method and simple BRDF model have been developed for estimating slant view response of forest canopy is described. The BRF model developed by using multi-angular measurement has been able to obtain structural information from canopy. In addition, we have conducted some observation campaigns of typical forest in Japan and China. We hope that the algorithm experienced with vegetation phenology and carbon flux measurement. Primary results of these observations will also be demonstrated. Based on above described observation results, authors have been developed a biomass estimation algorithm using a set of nadir and slant view sensor observed reflectance. The estimation algorithm for a specific forest type, which is for deciduous forest, has been applied to TERRA/AQUA MODIS data obtained 2010 summer. The result clarifies that the algorithm could achieve precise estimation in comparison to existing algorithm using vegetation indices.

8524-49, Session 6
The relationship between GPP and spectral reflectance for monitoring grassland status and carbon uptake in an alpine grassland in the Qinghai-Tibetan Plateau
Hideki Kobayashi, Japan Agency for Marine-Earth Science and Technology (Japan); Tomomichi Kato, Univ. de Versailles Saint-Quentin-en Yvelines (France); Shin Nagai, Japan Agency for Marine-Earth Science and Technology (Japan); Yanhong Tang, National Institute for Environmental Studies (Japan); Mingyuan Du, National Institute for Agro-Environmental Sciences (Japan)

The Tibetan plateau has experienced a warming trend. A process-based biogeochemical simulation suggests the Tibetan plateau changed from a small carbon source to sink throughout the 20th century. Satellite-derivation estimation also shows the increase in annual NPP in the last decade of the 20th century. This study focuses on how satellite observed reflectances, not conventional vegetation indices, correspond to seasonal and interannual variations in GPP in an alpine grassland site located in the northeastern part of Qinghai-Tibetan plateau. In this study, we investigate (1) how many reflectance measurements are available in our study site, by combining two satellite products: MODIS daily surface reflectance data sets and SPOT VEGETATION ten days synthesis (S 10)? (2) How the reflectance seasonality in red, near infrared and shortwave infrared corresponds to above ground green biomass and GPP? Compared with VI-based approach, can we expect a better estimation on above ground green biomass and GPP? And what the reflectance and GPP relationships tells us? (3) Is it possible to estimate seasonal and inter-annual (the years 2002 to 2010) above ground green biomass and GPP? We show how red, NIR and SWIR hysteresis diagram work for understanding the seasonal cycle of GPP, especially GPP decreases in autumn. The red and SWIR reflectances indicate strong hysteresis whereas NIR has a linear relationship with GPP. NIR linearly with GPP is closely related to the seasonal patterns in the grassland above ground green biomass.
8524-50, Session 6

Accuracy evaluation of satellite remote-sensing-based phenological observations in East Asia by performing long-term continuous ground-truthing and ecological examinations
Shin Nagai, Japan Agency for Marine-Earth Science and Technology (Japan); Takeshi Motohka, Japan Aerospace Exploration Agency (Japan); Hideki Kobayashi, Rikie Suzuki, Japan Agency for Marine-Earth Science and Technology (Japan); Hiroyuki Muraoka, Gifu Univ. (Japan); Kenzo N. Nasahara, Univ. of Tsukuba (Japan); Taku M. Saitoh, Gifu Univ. (Japan)

General, global, long-term, and comprehensive phenological observations are required to accurately evaluate the variability of terrestrial ecosystem structures, functions, and biodiversity due to environmental changes. Satellite remote-sensing (S-RS) is an useful tool to observe the spatio-temporal variability of vegetation with a high spatio-temporal resolution. However, S-RS data often include inaccuracy caused by such as snow cover on vegetation, cloud contamination, and atmospheric aerosols. From the in situ ecological research viewpoint, further field observations are required to obtain ground-truth for S-RS on various ecosystem sites. Toward this aim, first, we established a robust, long-term and continuous ground observation network for various ecosystem sites: “Phenological Eyes Network” (PEN; http://www.pheno-eye.org). Second, we examined the detection criteria for the timings of leaf-expansion and -fall by using daily canopy surface images and spectral reflectance data in PEN sites. Finally, we analysed the spatio-temporal variability of the timings of leaf-expansion and -fall in East Asia by applying our robust detection criteria for the TERRA/AQUA MODIS-observed daily satellite data between 2003 and 2011. The green-red ratio vegetation index (GRVI) value of 0.0 could detect the timings of leaf-expansion and -fall for various ecosystems except for the evergreen forests. Wrong evaluations of the timings of leaf-expansion and -fall were caused by cloud contamination or noise in the time-series of GRVI. Although further ground-truth for a range of ecosystems and sites are encouraged, our results could provide ecological evidences for S-RS-based phenological observations.

8524-51, Session 6

Retrieval of leaf area index using wireless sensor network
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Crop structural parameters, such as leaf area index and average leaf angle, are the main factors that can effect the solar energy re-assignment in the canopy. The traditional method to measure such parameters for crop, e.g., maize and wheat, is relied on the handy instrument, so it is difficulty to carry out the measurement on the large spatial region and on the long time series. An automatic measuring system which is designed on the basis of wireless sensors network (WSN) is present in this paper. The system is comprised of three types of node, i.e. two solar irradiance measurement nodes deployed beneath and above the canopy respectively, a sink node used to collect data from the measurement nodes and a route node acted as a repeater of wireless communication. Canopy structural parameters can be calculated from the direct transmittance which is the ratio of sun irradiance captured by the measurement node beneath and above the canopy on different sun altitude angles. Numeric simulation and the field preliminary validation results show that the designed system can detect the directional canopy transmittance which is the basis to calculate the target parameters. And the further calculation results reveal that the measured LAI values between LAI2000 instrument and our propose measurement system have high correlation coefficient and the calculated average leaf angles are very proximity to the theoretical values. So it is a promising way in the agriculture application to utilize the proposed system and thus can be an efficient way to measure the crop structural parameters in the large spatial region and on the long time series.

8524-52, Session 6

Assessing the sensitivity of two new indicators of vegetation response to water availability for drought monitoring
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Two new drought indicators based on satellite observations of vegetation index and land surface temperature, i.e. the Normalized Temperature Anomaly Index (NTAI) and the Normalized Vegetation Anomaly Index (NVAI) were applied to monitor drought events in different regions in China and India. Anomalies in such indicators were determined as the difference between the current values of the indicators and the mean values for the same period of time over the entire record of observations scaled by the difference of minimum and the maximum over the same record period. The daily time series of the two indicators were generated at the spatial resolution of 1 km using MODIS radiometric data. We carried out the analysis for drought events in 2006 in Sichuan-Chongqing, in 2009 in the South-Western provinces, Inner-Mongolia (China) and in the Ganga basin (India). The two new drought indicators NTAI and NVAI can distinguish the stages of drought evolution and respond consistently to climate forcing. In the present case studies, long lasting rainfall anomalies led to severe drought and anomalies in rainfall and LST appeared almost simultaneously. The LST anomaly once it appeared, it did not disappear, thus providing additional and useful information on the impending drought event, well in advance of the time of peak-severity. The sensitivity of the indicators to drought conditions and severity was evaluated against drought assessments by operational drought monitoring services and ground-based indicators. The results documented how well the indicators meet expectations on the timely and reliable detection of environmental change.

8524-53, Session 6

A novel method of scales transformation for quantitative remote sensing retrievals: fractal and its analysis, improvement
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Scale effect was the very important characteristics of remote sensing. The scale effect of quantitative remote sensing studied scale relationship among retrievals of different-resolution images, and correllative research became an effective way to confront the challenges, such as validation of quantitative remote sensing products, et al. Zhang et al., (2010) posed a fractal method to explore the correlation information and obtained very attracting result. Whereas, there were two significant problems of it: a. it was an essential precondition that make sure the retrieving model as precise as possible. Thus, it required mechanism models that presented physical course. So it was not suitable that LAI was retrieved by NDVI through statistic methods; b. the selection of basic variables for up-scale fusion was not suitable. Some retrievals that had linear rules of scaling in some cases should be selected, and complex retrievals were retrieved by the basic ones. So NDVI was not reasonable for LAI retrieval by up-scale fusion. Then the paper proposed an improved scheme and computation method of fractal scaling. Taking NDVI as example we did some experiments on TM image. The preliminary results indicated that the fractal rule of scaling existed for NDVI, and the correlation coefficient r, the p-value of the fitting line proved that the fractal dimension D was credible. Consequently we had the conclusions: the fractal method of scaling for quantitative remote sensing retrievals was effective and it was very meaning for the validation of them.
8524-55, Session 6
Quantification of human activity on NPP change during 2000-2010 in China
Juan Gu, Xin Li, Chunlin Huang, Lanzhou Univ. (China)

Despite the pervasive human impact on the global hydrologic and carbon cycles, robust estimates of such human impact on Net primary production (NPP) change during 2000-2010 are lacking. In this study, a quantification scheme was developed to quantify the effect of human activity on NPP change based on linear regression model. Here, we used a light-use efficiency model to describe the spatial and temporal patterns of terrestrial net primary productivity (NPP) in China during 2002-2010. First, we used a linear regression to simulate the effect of climate changes (temperature, precipitation and radiation) on NPP change, then we use error analysis method to obtain the human impact. For NPP estimation, we used the reconstructed 16-day 0.05°MODIS NDVI product (MOD13C1), 0.05°gridded GLDAS (Global Land Data Assimilation System) meteorological data and land use map to estimate the NPP in China. The spatial feature of the effect of climate and human factor on NPP change were analyzed during 2002-2010. The primary results showed that there were four influence centers: • 1 the southeast part of Qinghai-Tibet Plateau; • 2 the north part of Xinjiang; • 3 the north part of Guangxi province, the middle part and the northeast part of Yunnan province, and the south part of Guizhou province; • 4 the south part of Inner Mongolia. The influence of climate is decreasing from north China to south China. In north part of Qinghai-Tibet plateau, the arid and semiarid region, the NPP is sensitive to climate change. In plain and hilly region, the NPP was sensitive to human activity and was distributed with discontinuous pattern.

8524-56, Session 6
Study on forest above ground biomass synergy inversion from GLAS and HJ-1 data
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The need exists to develop a systematic approach to inventory and monitor global forests, both for carbon stock evaluation and for land use change analysis. The use of freely available satellite-based data for carbon stock estimation mitigates both the cost and the spatial limitations of field-based techniques. Spaceborne lidar data have been demonstrated as useful for aboveground biomass (AGBM) estimation over a wide range of biomass values and forest types. However, the application of these data is limited because of their spatially discrete nature. Spaceborne multispectral sensors have been used extensively to estimate AGBM, but these methods have been demonstrated as inappropriate for forest structure characterization in high-biomass mature forests. This study uses an integration of ICESat Geospatial Laser Altimeter System (GLAS) lidar and HJ-1 satellites data to develop methods to estimate AGBM in an area of Gilian mountains, Northwest China. Considering the study area belongs to mountainous terrain, the difficulties of this article are how to extract canopy height from GLAS waveform metrics and topographical correction for optical images. Combining with HJ-1 data and ground survey data of the study area, we establish forest biomass estimation model for the GLAS data based on BP neural network model. In order to estimate AGBM, the training sample data includes the canopy height extracted from GLAS, LAI, vegetation coverage and several kinds of vegetation indices from HJ-1 data.

8524-57, Session 6
Satellite remote sensing of photosynthetic potential of boreal forest in Alaska
Rikie Suzuki, Shin Nagai, Hideki Kobayashi, Japan Agency for Marine-Earth Science and Technology (Japan); Taro Nakai, Yongwon Kim, International Arctic Research Ctr. (United States)

The photosynthesis, that directly dominates the vegetation productivity, is a major controlling factor of the global carbon cycle. To estimate of the annual photosynthetic productivity of vegetation, it is essential to figure out the green leaf area index (LAI) of the vegetation, a biophysical parameter for the photosynthetic potential, and the growing season of the vegetation in a year. This study made an attempt to estimate the photosynthetic potential of boreal forests that extensively covers Alaska by using data of satellite remote sensing and field surveys. Two kinds of investigation were carried out: (a) monitoring of the forest seasonality based on photographs taken by the automatic fish-eye camera installed in a typical black spruce forest at Poker Flat Research Range (PFRR) of University of Alaska Fairbanks, and the subsequent analysis on the relationship between photography-derived seasonality and satellite-derived NDVI for the determination of the growing season; (b) development of the estimation algorithm of the forest LAI by the satellite remote sensing image and the in-situ LAI measurement acquired at PFRR. These investigations developed by this study will be applicable to the observation by the sensor "Second-generation GLI (SGLI)" of the satellite “Global Change Observation Mission (GCOM)-C” that will be launched in the future.

8524-58, Session 6
Mapping Sargassum beds off, ChonBuri Province, Thailand, using ALOS AVNIR2 image
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Sargassum species grow on rocks and dead corals and form dense seaweed beds. Sargassum beds play ecological roles such as CO2 uptake and O2 production through photosynthesis, spawning and nursery grounds of fish, feeding ground for sea urchins and abalones, and substrates for attached animals and plants on leaves and holdfasts. However, increasing human impacts and climate change decrease or degrade Sargassum beds in ASEAN countries. It is necessary to grasp present spatial distributions of this habitat. Thailnd, especially its coastal zone along the Gulf of Thailand, is facing degradation of Sargassum beds due to increase in industries and population. JAXA launched non-commercial satellite, ALOS, providing multiband images with ultra-high spatial resolution optical sensors (10 m), AVNIR2. Unfortunately, ALOS has terminated its mission in April 2011. However, JAXA has archived ALOS AVNIR2 images over the world. These images are still useful for monitoring coastal ecosystems. We examined capability of remote sensing with ALOS AVNIR2 to map Sargassum beds in waters off Sattahip protected area as a natural park in ChonBuri Province, Thailand, threatened by degradation of water quality due to above-mentioned impacts. Ground truth data were obtained in February 2012 by using continual pictures taken by manta tow. Supervised classification could detect Sargassum beds off Sattahip at about 70% user accuracy. It is estimated that error is caused by mixel effect of bottom substrates in a pixel with 10 x 10 m. Our results indicate that ALOS AVNIR2 images are useful for mapping Sargassum beds in Southeast Asia.

8524-59, Session 7
Possibility of mutual verification between satellite products and climate model simulation results
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In the Northern hemisphere, the CO2 concentration in the warm season indicated relatively high values in 2003, and low values in 2004. To investigate the reasons of the interannual variation, a numerical simulation using a land biosphere - atmosphere full couple GCM was carried out. Relationship between interannual variations of CO2 and those of the land surface elements was investigated. In
2003, high surface temperature and low soil wetness conditions in the Eurasian Continent and in North America, and low downward short wave radiation condition in East Asia, occurred in the warm season. It is considered that these climate conditions in 2003 induced relatively low GPP and NPP values in the continental scale. Comparison of the simulation results of GCM with satellite data (MODIS and AMSR-E) was performed concerning the remarkable interannual changes from 2000 to 2004. Global distributions of the seasonal changes by the model almost agree with those by the satellite data regarding both the land surface temperature and the soil moisture. The interannual changes of land surface temperature by the model agree well with those by the MODIS data. As to the soil moisture, the regions exist where the interannual changes by the model disagree with those by the AMSR-E data especially in the warm season. The values of elements calculated by the model are physically and biologically consistent each other in the model. Therefore, the model results are useful as the relative information for the validation of the global scale or regional scale products of satellite data estimated separately by each algorithm.

8524-60, Session 7
Multiple view angle effects on classification of forward-modelled MODIS reflectance
Ziti Jiao, Beijing Normal Univ. (China)

This study examines the effects of multiple view angles on the classification of forward-modeled, high-quality, multi-spectral reflectances in a Canadian boreal forest region using a decision tree classifier (C4.5). Bidirectional reflectance factors (BRFs) from the seven-band moderate resolution imaging spectroradiometer (MODIS) are reproduced from high-quality composite model parameter data sets that were retrieved using a daily rolling version of an operational algorithm developed for direct broadcast and that were successfully used in earlier research. The results show that the classification accuracies obtained from the model MODIS BRFs in the principal plane are not substantially different, with the exception of a few directions, relative to bi-hemispherical reflectances (the white sky albedo, or WSA) in the MODIS bidirectional reflectance distribution function (BRDF)/Albedo product. The highest and lowest overall classification accuracies are those acquired by the seven-band Nadir BRDF-Adjusted Reflectances (NBRs) (~77.745%±3.036) and the seven-band hotspot reflectances (~72.18±2.27%), respectively. Analysis of per-class accuracies of eight land cover classes with different structures shows that the Herb class and the Broadleaf dense class have high per-class accuracies (mostly greater than 90%) from various view angles whereas other classes have relatively low per-class accuracies that tend to change with the view zenith angle (VZA) and that are somewhat higher in the close-to-nadir and backward directions relative to the forward scattering directions. Further investigation reveals that the classification accuracies derived from the reproduced MODIS BRFs are negatively correlated with the within-class variances of these BRF input features.

8524-62, Session 7
Monte Carlo modeling in problems of land surface aerospace sensing
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Photometric and spectral measurements are widely applied in developing of aerospace methods of optical sensing of the Earth’s surface. Commonly in this case three classes of corresponding problems can be defined:
1. The optical properties of the atmosphere, optical properties of objects on the Earth’s surface and the sensing conditions are known. It is required to find out the photometric or spectral properties of the echo-signal registered in space.
2. The optical properties of the atmosphere, photometric or spectral properties of the registered echo-signal and the sensing conditions are known. It is required to find out the optical properties of objects on the Earth’s surface.
3. The photometric or spectral properties of the echo-signal registered in space, optical properties of objects on the Earth’s surface and the sensing conditions are known. It is required to find out the optical properties of the atmosphere.

In this paper application of the Monte Carlo method to the first two classes of problems is considered. More specifically, the problem (let’s call it “direct”) of modeling an echo-signal from a known area of the Earth’s surface and the problem (it’s natural to call it “inverse”) of filtering atmospheric distortions of the registered signal, i.e., recovering true optical properties of objects on the Earth’s surface knowing the echo-signal. In these cases the optical properties of the atmosphere and the sensing conditions are considered to be known.

The approach considered in this paper is entirely based upon the principles of the linear optical systems theory. The process of transfer of solar radiation is described by a transfer equation with randomly-inhomogeneous optical parameters. A new algorithm of the Monte Carlo method for estimating the optical transfer function (OTF) of the system atmosphere-underlying surface. Certain results of numerical computations of the OTF in a stochastic atmosphere and examples of a test optical correction of atmospheric distortions of “space images” of the Earth’s surface are presented.

8524-63, Session 7
Parametric representation of soil isoline equation and its accuracy estimation in red-NIR reflectance space
Kenta Taniguchi, Yasuhiro Ikuta, Aichi Prefectural Univ. (Japan); Kenta Obata, Univ. of Hawai‘i (United States); Masayuki Matsuoka, Kochi Univ. (Japan); Hiroki Yoshioka, Aichi Prefectural Univ. (Japan)

Retrieval of biophysical parameters from remotely sensed reflectance spectra often involves algebraic manipulations, e.g. spectral vegetation index, to enhance pure signals from a target of one’s interest. An underlying assumption of those processes is an existence of high correlation between an obtained value from the manipulations and amount of the target object. These correlations can be seen in scatter plots of reflectance spectra as “isolines” that represent a relationship between two reflectances of different wavelengths (bands) under constant values of physical parameters. Therefore, modeling the isolines would contribute to better understanding of retrieval algorithms and eventually to improve their accuracies. The objective of this study is to derive one such relationship observed under a constant spectrum of soil surfaces, known as soil isolines, in red-NIR reflectance space. This work introduces a parametric representation of the soil isolines (soil line equation) with the parameter obtained by computing the red-NIR reflectance space by approximately a quarter of pi radian counter clockwise. The accuracy in the soil line equation depends on the order of polynomials used for the representations: It was investigated numerically by conducting experiments with radiative transfer models for vegetation canopy. The results showed that when the first-order approximation were employed for both bands the accuracy of the parametric representations/approximations of the soil isolines is approximately 0.02 in terms of mean average difference from the simulated spectra (with no approximation). The accuracies improved dramatically when one retains the polynomial terms up to the second-order for both bands.

8524-64, Session 7
Influences of band-correlated noise on FVC by VI-isoline based LMM: characteristic behavior of propagated error
Yasuhiro Ikuta, Kenta Taniguchi, Aichi Prefectural Univ. (Japan); Kenta Obata, Univ. of Hawai‘i (Japan); Masayuki Matsuoka, Kochi Univ. (Japan); Hiroki Yoshioka, Aichi Prefectural Univ. (Japan)

Fraction of vegetation cover (FVC) has been used for environmental studies of both regional and global scale, and data products of similar kinds have been generated from several agencies. Although there are differences in sensors/datasets used and algorithms employed among those products, many of those use spectral mixture analysis either directly or indirectly, and/or assume an essence of spectral mixture in their models. In the FVC estimations, noises in reflectance spectra of both target and endmember are propagated into the estimated
FVC. Those propagation mechanisms such as patterns and degree of influences need to be clarified analytically, where this study tries to contribute. The objective of this study is to investigate characteristics of the noise propagation into the estimated FVC based on one of the linear mixture models known as VI-isoline based LMM. In order to facilitate analytical discussions, the number of endmember spectra is limited to two. In addition, a band-correlated noise is assumed in both reflectance spectrum of a target pixel and endmember spectra of vegetation and non-vegetation surfaces. The propagated error in FVC from those spectra is analytically derived. The derived expressions indicated that the characteristic behavior of the propagated errors exists such that there are certain conditions among the band-correlated noises which result in the cancellations of propagated errors on FVC value (it looks as if the spectra are noise-free). Findings of this study would reveal unknown behavior of the propagated noise, and would contribute better understanding of FVC retrieval algorithms of this kind.

8524-65, Session 7
Mapping spatial and temporal continuous daily land surface shortwave albedo with MODIS and AMSR-E data
Ying Qu, Lizhao Wang, Youbin Feng, Gongqi Zhou, Qiang Liu, Suhong Liu, Beijing Normal Univ. (China)

Land surface shortwave broadband albedo is a critical parameter in global change studies. For most of applications, long time series, spatial and temporal continuous albedo product is needed, however, the optical sensor is usually affected by cloud coverage. While the passive microwave data is less sensitive to the atmosphere and clouds, which can be employed for estimating shortwave broadband albedo base on establishing a statistical relationship between the shortwave albedo and microwave data by an artificial neural network (ANN) method. Finally, the albedo estimated by optical (MODIS) and microwave (AMSR-E) data is fused by a Bayesian Maximum Entropy (BME) theory.

8524-66, Session 7
Comparison between the research result of mathematical morphology method applied to satellite SAR data and the other reported results for the detection of the 2011 off the Pacific coast of Tohoku Japan earthquake and tsunami-affected farmlands
Yasuharu Yamada, National Agriculture and Food Research Organization (Japan)

A great earthquake and following great tsunami occurred on 11th March 2011 over the wide areas of the north-east of Japan. The agricultural fields along the coast were submerged under the seawater caused by the Tsunami tidal wave for some periods. The soil in such farmland suffered from salt of sea water. As soil salinity is hindrance to the plants, the detection of Tsunami flooded farmland is important for agriculture. ALOS satellite data were obtained from March 13th including both optical sensor data and SAR data. And aerial photograph for photogrammetry was taken from the next day of the earthquake by Geospatial Information Authority of Japan. Many research institutes and universities performed ground survey and made Tsunami flooded extent maps in that region. But as for cloud and large areas, SAR data has advantage. Therefore the author tried to detect the Tsunami flooded extents from ALOS/PALSAR HH data. The outline of the procedure of the analysis is threshold method for extracting the low backscattering areas as a black and white color image, opening operation of mathematical morphology using 3 by 3 filter size for clearing small islands, dilation operation of mathematical morphology using 3 by 3 filter size to establish united areas in the scene. The obtained image is compared to aerial photograph and ground survey maps.

8524-67, Session 7
Supporting elephant conservation in Sri Lanka through MODIS imagery
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The latest national elephant survey of Sri Lanka (2011) revealed the number as 5,879. The total forest cover for these elephants is about 19,500 sq km (2012 estimation). The estimated forest area is about 30% of the country but, smaller green patches are also counted under forest. However, studies have pointed out that a herd of elephants need about a 100 sq km of forest patch to survive. With a high human population density (332 people per sq km, 2010), the pressure for land to feed people and elephants is becoming critical. Recent reports have indicated about 250 elephants are killed annually by farmers and dozens of people are also killed by elephants. Under this context, apart from various local remedies for this issue, the conservation of elephant population can be supported by satellite imagery based studies. MODIS sensor imagery can be considered as a successful candidate here. Its spatial resolution (250m x 250m) automatically filters out small forest patches in the mapping process. The daily imagery helps to monitor temporal forest cover changes, which helps to understand local level movements of elephants. However, the coarse image resolution is not capable to delineate forest-village. This study used MODIS 250m imagery to map Sri Lanka's forest cover (2012) and identified sizeable forest patches for elephants. High resolution Google Earth images were used in accuracy assessment and to examine forest-village environment. The elephant movement information was gathered from local authorities and existing and potential bio-corridors were tried to identify. In future research steps, monthly forest cover maps and field investigations will help to establish a clear understanding of elephant movements.
Evaluation of sea surface salinity observed by Aquarius on SAC-D
Naoto Ebuchi, Hiroto Abe, Hokkaido Univ. (Japan)
A passive and active L-band microwave sensor, Aquarius, developed by NASA to observe the global sea surface salinity (SSS) distribution, was launched on 10 June 2011. The SSS observed by Aquarius was evaluated by comparison with in-situ salinity data from various sources. The Aquarius SSS generally agreed well with Argo salinity in high sea surface temperature (SST) regions. However, the Aquarius SSS highly deviated in low SST and high wind regions. The rms difference was relatively small in low latitude (0.5 – 0.6 psu at 10°N – 10°S), and large in the high latitude (0.8 psu at 60°N, 1.0 – 1.9 psu in the south of 40°S). If we used the colocate data observed from Aquarius BUTT and Argo, the number of data was 10,768, bias (Aquarius - Argo) was -0.15 psu, rms difference was 0.66 psu, and correlation coefficient was 0.79. Intensity of noise from the sea surface basically depends on the SST, wind speed, wind direction and SSS. At low SST, the dependence of the brightness temperature on SSS is relatively weak. Under this condition, effects of wind are considered to be relatively important. This is consistent with the large deviation of Aquarius SSS in the high latitude. We also found that the SSS residual depends on the wind direction relative to the sensor looking direction.

Effective monitoring for marine debris after great east Japan earthquake by using spaceborne synthetic aperture radar
Motofumi Airi, Yoshifumi Aoki, Masakazu Kolwa, Mitsubishi Space Software Co., Ltd. (Japan)
The Great East Japan Earthquake occurred at March 11, 2011 and caused massive tidal wave. The tsunami swept away a large quantity of rubble and vessels to the sea and they become so-called marine debris. To assess damage situation and protect marine environment, it is essentially required to investigate the status of those marine debris. The technique based on spaceborne synthetic aperture radar (SAR) can be a strong candidate to achieve this ultimate goal, because of its wide observation area and higher resolution with flexible operability: regardless of the day and night and regardless of the weather. We have monitored marine debris on huge amount of spaceborne SAR imagery right after the great disaster and an effective observation of marine debris to predict future direction.

In this paper, we firstly define three types of debris as Large Debris, Small Debris, and Cluster by considering how marine debris looks like on SAR imagery. Then, an automatic but accurate detection and classification of a large amount of debris on SAR imagery is proposed. Based on those results, resolution and swath width for efficient marine debris monitoring are obtained. Velocity of marine debris is additionally estimated from multi-temporal SAR images to derive optimum swath width. We may also describe how the observation is affected by varying not only incidence angles but also polarization.

A new PolSAR ship detector on RADARSAT-2 data
Yuan Sun, Hong Zhang, Chao Wang, Fan Wu, Bo Zhang, Ctr. for Earth Observation and Digital Earth (China)
In this paper, a new ship detector in marine area based on RADARSAT-2 Quad Mode data is proposed. The Freeman-Durden three-component decomposition method is first applied on the data to decompose them into 3 scattering mechanisms: double-bounce scattering, surface scattering and volume scattering. Comparing to ocean clutter, ships are man-made structures which are characterized by strong double-bounce scatterings caused by cabins and other buildings on the ships and by strong volume scatterings caused by the complex structures. Thus the detector utilizes these two features to detect ships. First of the three decomposed elements are arranged as a vector. Then project the vector into two subspaces, one with only double-bounce scattering and volume scattering, the other one with some geometrical perturbation which is slightly different from the first one. The detector correlates the two projected vectors. If the target is dominated by double-bounce scattering and volume scattering (ships), the coherence of the two vectors is high, and if it is only dominated by double-bounce scattering (azimuth ambiguity), or volume scattering (system noise), or surface scattering (sea surface), the coherency is low. Thus a threshold can be set to discriminate ships from ocean clutters and false alarms. This detector was tested on RADARSAT-2 data and the results showed that it detected ships on the image precisely with few miss detected ships and false alarms. This proposed method provides a better performance compared with HH-CFAR detector, HV-CFAR detectors, and widely used PWF detector.

Civilian ship classification based on structure features in high resolution SAR images
Shaofeng Jiang, Hong Zhang, Chao Wang, Fan Wu, Bo Zhang, Ctr. for Earth Observation and Digital Earth (China)
Ship classification is an important research area, as it can help to improve surveillance and control activities. By making use of the new generation SAR satellites like COSMO-SkyMed and TerraSAR-X, civilian ship classification in high resolution SAR images is a hotspot and preceding problem in SAR applications. According to the different features of cargo ships, oil tanker and container ships in high resolution SAR images, we proposed a method based on structure features to classify these three ship types. The method had the following three main stages. Firstly, in terms of the imaging characteristics of the sidelobe, a morphological pre-processing was used to diminish its impact on subsequent classification. Secondly, the major axis and Minimum Enclosing Rectangle (MER) were extracted by using PCA (Principal components analysis). Then, the longest axis along the direction of major axis was obtained. Finally, the three main structure features, including the width ratio of MER between the longest axis, the autocorrelation coefficient and the Kernel Density Estimation (KDE) were calculated to classify the ship types.

In order to achieve a true and reliable experimental data, we carried out a synchronous experiment over East China Sea when COSMO-SkyMed was transiting. The classification method was tested with several COSMO-SkyMed images. AIS (Automatic Identification System) data was used to verify the classification accuracy. The result shows that this ship classification method has good performance in high resolution SAR images, whose average precision is up over 80%.
Radon transform computes the projection of the image in all directions. A point in the transform domain represents a straight line in the image plane. Because of the ability to extract line features, Radon transform is still the most popular tool in ship wake detection. However, whether global or localized Radon transform is used, the result is an image rather than a linear feature with endpoint. In addition, the computational complexity of Radon transform is big.

This paper presents a novel normalized scanning algorithm for detecting ship wakes in SAR (Synthetic Aperture Radar) images. The technique takes advantage of the displacement between the ship and perspective wake in azimuth direction. The proposed algorithm can determine the offset in azimuth direction and the movement direction of ship. Then we can get the velocity vector of the ship. Although the computational complexity is very small, the normalized scan algorithm is robust in high noise environment. Experimental results show that the ship wake detection based on normalized scan is better than traditional technique.

8525-6, Session 1
On oil films detection on the sea surface using optical remote sensing method
Irina Sergievskaya, Stanislav A. Ermakov, Institute of Applied Physics (Russian Federation)

Oil films detection and discrimination from films of another origin is a very important ecological problem. Remote sensing methods, particularly, satellite methods are the most perspective for the problem solution. Films in the sea surface optical images can be seen because of changing a) the reflected radiance due to strong depression of short gravity-capillary waves by films and b) the reflection coefficient when considering light reflection from two boundaries of the film. Therefore sea surface radiance variations are strongly determined by film parameters. Natural biogenic films spread down to monomolecular layers and can be characterized by the elasticity and the surface tension coefficient. Oil films have finite thickness values and wave damping due to these films is determined by larger number of physical parameters, such as the oil density, film thickness, viscosity and elasticity of two film boundaries, etc. Possibilities of film slick detection and characterization using optical systems of low spatial resolution are analyzed. The threshold values of the film parameters at which film slicks can be detected using these systems are estimated at different observation/illumination conditions and wind waves regimes. The principal possibility to estimate the film parameters and to identify oil films is demonstrated using a theoretical model. Experimental verification of the model is presented based on measurements of the sea surface radiance contrast in slicks with known film parameters. This work has been supported by the Russian Foundation of Basic Research (projects 11-05-00295, 11-05-97027, 10-05-00101, 11-05-97029) by the RF Ministry of Education and Science (Contracts &8470;11.G34.31.0048, &8470;11.G34.31.0078).

8525-7, Session 1
Slicks on the sea surface: their origin and remote sensing
Stanislav A. Ermakov, Institute of Applied Physics (Russian Federation)

An overview of studies of marine slicks and slick remote sensing at IAP RAS is presented. Radar and optical images of slicks due to different oceanic/atmospheric processes are considered, including oceanic internal waves, non uniform currents, wind fronts, algae bloom, oil spills. Surface manifestations of internal waves have been studied using radar and optical probing of surface waves simultaneous with measurements of characteristics of internal waves and surfactant films. Variations of the spectrum of short wind waves are analyzed theoretically and theory is shown to explain observations. “Filamentary” slicks in radar/optical images related to marine currents have been investigated when measuring film characteristics and current velocities inside/outside the “filaments”. It is shown that the “filaments” are stretched along the main streams and are formed due to the interaction of fast varying ocean current components and slow varying oceanic currents. Slicks due to film compression by the wind drift are illustrated by observations of periodic and solitary slick bands in the field of oscillating and step-like wind fronts. Manifestations of algae bloom in radar images are discussed. The radar backscatter is shown to decrease with phytoplankton concentration in the upper water layer. The effective water viscosity and film thickness due to algae is considered as the main physical reason of the radar backscatter depression. Results of experiments on radar and optical remote sensing of films with pre-measured physical characteristics are analyzed, and dependencies of the damping degree of wind waves (spectrum contrast) on wavelength are obtained at different wind conditions and different films. A model of wave damping is developed and is shown to describe satisfactory experiment. Possibilities of slick identification from remote sensing data are discussed.

8525-8, Session 1
Retrieval of swell parameters using PALSAR onboard ALOS and its application
Yongliang Wei, Shanghai Ocean Univ. (China); Hiroshi Kawamura, Tohoku Univ. (Japan); Zeyan Tang, East China Sea Prediction Center, State Oceanic Administration of China (China)

We have developed retrieval methods for swell parameters, i.e., wave height, wavelength, and wave direction from images of the Phased Array type L-band Synthesis Aperture Radar (PALSAR) on board the Advanced Land Observing Satellite (ALOS) taken over coastal seas around Japan. The retrieval methods for wavelength and wave direction use the PALSAR image spectrum which has an inherent 180° direction ambiguity, which can be solved considering that waves propagate toward the satellites. Using theoretical calculations and the PALSAR image spectra, an empirical L-band modulation transfer function was obtained for wave height retrieval through linear regression analysis. A comparison between SAR-derived and in situ wave parameters shows that wavelength, wave height, and the bias was 10.4 m, the root mean-square error was 18.3 m, and the correlation coefficient was 0.93. For wave direction, the above three statistical values were 1.3°, 15.5°, and 0.94, respectively. These results demonstrate that the L-band SAR imaging mechanism for waves is non linear. For waves with statistical values were 0.08 m, 0.30 m and 0.80, respectively. As an application of the retrieval methods, a high-resolution two-dimensional map of swell wavelength and direction was retrieved from the scene observed on 2006/9/24 over Sendai Bay in the Tohoku region of Japan. The bathymetry of Sendai Bay was then obtained from the map by using the in situ tomographic amplitude surface wave theory, considering that swells interact strongly with coastal bottom. The result will be compared with a 500 m resolution bathymetry data.

8525-9, Session 1
Measurement of ocean waves using a cross-track interferometric SAR technique
Akitsugu Nadai, Toshihiko Umehara, Makoto Satake, Tatsuharu Kobayashi, Seiho Uratsuka, Seiko Sakwe, National Institute of Information and Communications Technology (Japan)

In this paper, the cross-track interferometric technique of synthetic aperture radar (SAR) is applied to ocean surface to measure ocean surface waves. The observation was made by the airborne SAR, Pi-SAR, developed by National Institute of Information and Communications technology and Japan Aerospace Exploration Agency. Because the X-band radar of Pi-SAR has interferometric function designed to land topography measurement, the accuracy of topography measurement is only 2m. However, under an assumption of the spatial uniformity of ocean waves in measured area, the spectra of ocean surface waves may be able to measure with high accuracy. A small area of ocean was observed by the Pi-SAR with many illumination azimuths. The current measurement of ocean wave spectra using SAR is based on the spectral analysis of intensity image. Because the intensity of ocean surface waves decreases with illumination azimuth, the intensity relation of spectral components on the resultant intensity spectra differ with the illumination azimuth. On the other hand, the interferometric SAR measures ocean topography directly, the intensity relation of spectral components on the resultant topography spectra is independent of the illumination azimuth. Moreover, the influence of random noise in the measured topography only raised noise floor of resultant topography spectra.
The results represent the ability of cross-track interferometric SAR technique not only to measure the ocean waves, but also to the topography of ocean surface. This result may become one of the feasibility studies of such a new ocean altimeter using interferometric SAR technique.

8525-10, Session 1

Seasonal and inter-annual variability of sea surface temperature and sea surface wind in the eastern part of Indonesian Sea: ten years analysis of satellite remote sensing data

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The overall objective of this study is to gain an improved understanding of the sea surface temperature (SST), sea surface wind speed (WS) and sea surface wind direction (WD) variability in the Eastern part of Indonesian Sea in response to the seasonal and interannual variations. The statistical properties and monthly average data for the 10-year period from December 1999-November 2009 in the Eastern part of Indonesian Sea are investigated by integrated use of TRMM Microwave Imager (TMI) of the Tropical Rainfall Measuring Mission (TRMM) and SeaWinds on the Quick Scatterometer (QuickSCAT) satellite remote sensing data. The time series shows a high variability of SST and WS (unstable areas) in the southern equatorial (3S-15S) in contrast with the stable condition around equatorial region. This condition related to the effect of prevailing winds in the Indonesian inland seas, which is WD varies seasonally. North-south (zonal) change of SST and WS are observed. These overall analyses confirm several characteristics of the Eastern part of Indonesian Sea.

8525-11, Session 2

Spatio-temporal geostatistical data fusion technique for merging MODIS and AMSR-E SST products

Yanchen Bo, Aihua Li, Yuxin Zhu, Beijing Normal Univ. (China)

Merging multi-sensor sea surface temperature (SST) products to take advantage of the complementary nature of each product can improve the quality of SST products to meet the requirements of the users in terms of estimation accuracy and data consistency. This paper proposes a spatio-temporal Geostatistical fusion technique based on the Bayesian Maximum Entropy (BME) method that incorporates multiple sensor’s SST observations, uncertainties lies in each observation, and their spatio-temporal variation knowledge to improve the SST estimation. The proposed BME fusion algorithm operated on both fine and coarse spatial resolution to accommodate the scale issue. The dynamic harmonics regression (DHR) method and an error model are proposed to address the issue of time trend and the incompatible spatial resolutions among different SST datasets (SSTs). By merging the two SST products, the availability of the blended SSTs increases from MODIS SSTs of 80% and AMSR-E SSTs of 87% to more than 95%. Comparisons with the drifting buoy observations in 2003 show that the proposed method can improve SST product consistency and achieve an acceptable accuracy. After data integration, the root mean square error (RMSE) increases from 0.589°C to 0.772°C over Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) SST. The increase (0.06) of RMSE over Moderate Resolution Imaging Spectroradiometer (MODIS) products is not as significant as that over AMSR-E SST. The mean bias (Bias) of the SST estimate is negatively increased from AMSR-E’s -0.125°C and MODIS’s -0.272°C to -0.344°C. The mean local value of merged SSTs is 0.241°C, which is approximate to that of MODIS SSTs (0.240°C), and larger than that of AMSR-E SSTs (0.053°C). The changes of availability and local variance of SSTs after and before blending show BME integrating the temporal-spatial information of MODIS and AMSR-E SSTs can capture the spatial structures at fine scale and improve the temporal-spatial continuity.

8525-12, Session 2

SAR monitoring of coastline changes of Nanhu New City, Shanghai, China

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In this paper, a semiautomatic method based on image segmentation was applied to extract the waterline from SAR (Synthetic Aperture Radar) images and the result is used to monitor the coastline changes of Nanhu New City, a coastal new city of Shanghai, China. About ten ERS-1/2 and ENVISAT SAR images acquired between 1996 and 2007 were carefully selected and a land-water classification scheme was implemented. The coastline of Nanhu New City during 1996 and 2007 were extracted. Using an optical remote sensing imagery, the accuracy was validated. With promising results, we quantified and analyzed the coastline changes between 1996 and 2007 in Nanhu New City, Shanghai, China. The results support further monitoring of coastlines in estuaries and coastal zones using active remote sensing.

8525-13, Session 2

Mesoscale and submesoscale eddies in SAR and optical images

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Mesoscale and submesoscale eddies play an important role for mixing, vertical transport, or biogeochemical processes. A large number of factors and wide variety of natural conditions in the ocean explain inevitable knowledge gaps concerning formation, evolution and propagation of eddies. The development of satellite remote sensing has evoked a considerable advance in the studies of these processes.

For remote sensing study of small-scale eddies, test regions of the Black, Baltic and Caspian Seas were chosen. The primary sources of data for this study are radar images obtained by the ASAR Envisat and the SAR ERS-2. In order to raise the quality of SAR data interpretation the study also involves optical and near-infra-red images.

Detailed measurement of parameters of submesoscale eddies and coastal currents was performed during submarines experiments which included cross-shelf CTD sections and towed ADCP surveys with submesoscale resolution. Interannual and seasonal variations and spatial distribution of vortical activity in the test areas were estimated. The largest quantity of eddies are detected in spring and summer (April-September). Seasonal eddy distribution variations are related to the yearly cycle of synoptic and mesoscale circulation in the basins.

The main mechanisms of generation of submesoscale eddies in the test areas are established. They are: instability of the near surface atmospheric layer, transformation of mesoscale vortical structures, variations of coastal current associated with flows by local coastal features, river plumes. Significant role of atmospheric and hydrological fronts and current instability in small-scale eddies generation are discussed.

8525-14, Session 3

Estimation of inherent optical properties using in-situ hyperspectral radiometer and MODIS data along the east coast of New Caledonia

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Hyperspectral remote sensing reflectance (Rrs) was measured by a TriOS radiometer system along the east coast of New Caledonia.
during the R/V Alis 03-13 October 2011 CALIOPE cruise. The TriOS system consists of radiance and irradiance sensors with a spectral range of 350 nm to 950 nm, a spectral resolution of about 10 nm (sampled by every 3.3 nm), and a 7-degree field-of-view for the radiance sensor. The method developed by Froidfond (2005) was used to determine Rrs, i.e., the radiation sensor was mounted on a small raft to measure water-leaving radiance just below the surface, and Rrs was calculated by normalizing water-leaving radiance with downward solar irradiance measured on the ship. Inherent Optical Properties (IOPs), i.e., absorption coefficients of phytoplankton and dissolved substances (aph and adg, respectively), and particulate backscattering coefficient (bbp) were estimated from the hyperspectral Rrs data by applying linear matrix inversion (Hoge and Lyon, 1996). The spectral characteristics of aph were compared with aph spectra of picoplankton and microplankton from Ciotti et al. (2002). Local characteristics of the IOP spectra were used for the candidate spectra in the satellite IOP algorithm applied to Aqua MODIS L1B data at 500 m resolution, to demonstrate the feasibility of regular IOP monitoring in the study area. The estimated MODIS Rrs and IOPs were evaluated using TriOS Rrs and in-situ IOP measurements obtained concomitantly during the cruise.

8525-15, Session 3
Monitoring the diffuse attenuation coefficient Kd in open and turbid waters from ocean color images using a neural network inversion
Cédric Jamet, Hubert Loisel, David Dessaully, Lab. d’Océanologie et de Géosciences (France)
The fine-scale study of the diffuse attenuation coefficient, Kd(lambdas), of the spectral solar downward irradiance is only feasible by ocean color remote sensing. Several empirical and semi-analytical methods were developed for the past three decades. However, most of these models are generally applicable for clear open ocean waters. They show limitations when applied to coastal waters. A new empirical method based on neural networks (NN) was developed using a relationship between the remote-sensing reflectances between 412 and 670 nm and Kd. The calibration of the new NN inversion was done using synthetical and NOMAD datasets. An NN method was developed for the SeaWIFS, MODIS, and MERIS sensors. Comparisons with the SeaWIFS empirical and semi-analytical algorithms show similar retrievals accuracies for low values of Kd(490) (i.e, <0.20 m-1) and better estimates for greater values of Kd(490). The new model is suitable for open water but also for turbid waters and does not show the limitations of the empirical and semi-analytical method. Results for MODIS and MERIS will be also presented.

8525-17, Session 3
Estimation of total suspended matter from three near infrared bands
Mitsuhito Toratani, Tokai Univ. (Japan); Joji Ishizaka, Nagoya Univ. (Japan); Yoko Kiyomoto, National Fisheries Research Institute (Japan); Yu-Hwan Ahn, Sinjae Yoo, Korea Ocean Research & Development Institute (Korea, Republic of); Sang-Woo Kim, National Fisheries Research and Development Institute (Korea, Republic of); Junwuu Tang, National Satellite Ocean Application Service (China)
Total suspended matter concentration (TSM) algorithms for ocean color sensors use satellite-retrieved remote sensing reflectances after atmospheric correction. It is difficult to estimate high TSM because such reflectances have some error in high TSM area. We developed a new estimation scheme of TSM using three bands at near infrared for MODIS/Aqua. We applied this scheme to MODIS/Aqua data and satellite-derived TSM were compared with ship-observed TSM dataset in Yellow Sea and East China Sea. RMSE was 0.338 on log scale and correlation coefficient was 0.850. The scheme was better than Clark or Tassam TSM algorithm.

8525-35, Session PSWed
SMOS sea surface salinity validation and application in South China Sea
Yongzheng Ren, Ctr. for Earth Observation and Digital Earth (China)
Soil Moisture and Ocean Salinity (SMOS) launched in November 2009 by European Space Agency (ESA) is the first satellite sensor to detect soil moisture and ocean salinity. For the first time, Sea Surface salinity (SSS) could be measured from space in human history. SMOS is expected to produce global maps of SSS with an accuracy of 0.1-0.2 practical salinity unit (psu) at a spatial resolution of about 100 km using the only payload of L-band Microwave Imaging Radiometer using Aperture Synthesis (MIRAS). The SSS products produced by ESA over the semi-enclosed South China Sea with complex sea state are needed to be validated. Based on this point, in this paper the SSS products released by ESA retrieved with three kinds of sea surface roughness models are validated with in situ measurements in South China Sea fall cruise funded by National Natural Science Foundation of China. Simple spatio-temporal aggregation of SSS products to generate weekly average SSS at 0.25° × 0.25° spatial resolution is validated with in situ data to analyze the influence of spatial resolution on SSS products and the error change law. The difference of SSS products retrieved with ascending and descending data are also studied.

8525-36, Session PSWed
A preliminary study on the application of remotely sensed SST in locating evaporation duct height
Muhammad Hasan A Baig, Institute of Remote Sensing Applications (China); Zhenhui Wang, Nanjing University of Information Science and Technology (China); Lifu Zhang, Institute of Remote Sensing Applications (China); Lu Yang, Zhe Wang, Nanjing University of Information Science and Technology (China)
Refractivity happens due to stratification in the lower boundary layer over oceans due to variability of different parameters which collectively may lead to generate evaporation duct (ED). This ducting sometimes supports normal propagation of EM signals and sometimes may cause distortion of signals depending on the height of ED. This leads to over-/under-estimation of target by radars. The aim of this study is to locate ED so that results may be used in applying correction measures both in military operations and also in radar meteorology by using remote sensing data. Data is processed through WRF and Babin’s method is used for calculating duct height. Very clear duct heights have been calculated at different areas over South China Sea in different time domains. Some potential areas are located with maximum EDH. It is found that in most of the cases EDH was higher when relative humidity was comparatively lower and air temperature and wind speed were comparatively higher. Study finds negative correlation between RH and T, wind & EDH. This study paves a way for futuristic study of ED monitoring and forecasting by assimilation of satellite RS data with radar data.

8525-37, Session PSWed
Accelerating ocean radiative transfer simulation using GPU with CUDA
Keiping Du, Kun Xue, Beijing Normal Univ. (China); Zhongping Lee, Univ. of Massachusetts Boston (United States)
Ocean Radiative Transfer Equations (RTE) is a complex integro-differential equation, which can be solved by different numerical methods, e.g., Monte Carlo ray tracing, invariant imbedding, and discrete ordinates. Monte Carlo method is a powerful technique, which can be used in any water body, even those whose boundary conditions and inherent optical properties (IOPs) vary in three dimensions, however, Monte Carlo methods are computationally costly, which limits their use for many problems in optical oceanography. In this paper, a new kind of acceleration technology to
accelerate the ocean radiative transfer simulation, using the CUDA-enabled graphics processing unit (GPU) is presented. The GPUs with CUDA offer desktop massive parallelization that can accelerate Monte Carlo computations, and can get a balance between the cost and performance. The CUBLAS and ArrayFire are powerful libraries for programming on NVIDIA GPUs. Their hardware details of a specific GPU. Firstly, some basic ideas of GPU programming is introduced. Finally, GPU programs for ocean radiative transfer simulation are implemented, and their performance with their GPU counterparts are compared. From our numerical results, around 100x speedup is achieved.

8525-38, Session PSWed

Status and threats on seagrass beds using GIS in Vietnam
Cao V. Luong, Nguyen V. Thao, Institute of Marine Environment and Resources (Viet Nam); Teruhisa Komatsu, Atmosphere and Ocean Research Institute (Japan)

Seagrasses, marine flowering plants, are widely distributed along temperate and tropical coastlines of the world. Seagrasses have keys ecological roles in coastal ecosystems and can form extensive meadows supporting high biodiversity. Till now, fourteen seagrass species were found in Vietnam belong four family Hydrocharitaceae, Ruppiaceae, Zosteraeaceae and Cymodoceaceae. Including Halophila beccarli, H. decipiens, H. ovalis, H. minor, Thalassia hemprichii, Enhalus acoroides, Ruppia maritime, Halodule pinifolia, H. unineris Siringodium isosetifolium, Cymodoceaprotunda. C. Serrulata and Thalassodendron ciliatum. Total area of seagrass beds in Vietnam is estimated by satellite images and GIS technology approximately 17,000ha. In recent years, the seagrass beds in Vietnam has been serious decline on the distribution areas and cover percentage when comparing to 10 - 15 years ago. The decline limit that depend on the impacts from the natural progress and the economical activities and the conservation awareness to them is different at every coastal areas.

In general speaking, the distribution areas and cover percentage of seagrass beds is decreased above 50%. In some distributed areas as Quangninh, Haiphong, Phu Quoc coastal tidal flats seagrass seem be loosen nearly complete. The distribution areas of seagrass beds that measured in 2009 at Tam Giang - Cau Hai Lagoon (Thua Thien Hue Province) and Cua Dai river mouth (Quangnam Province) is decreased about 50 - 70% when compared in the early 1990s.

8525-39, Session PSWed

Monitoring of debris flow in the ocean generated by huge tsunami caused by the 2011 off the Pacific coast of Tohoku earthquake
Takashi Aoyama, Fuku University of Technology (Japan)

The 2011 off the Pacific coast of Tohoku earthquake (Mw = 9) was one of the most devastating earthquakes in Japanese history. The extremely large and widespread tsunami it generated caused a large amount of debris to flow into the Pacific Ocean. It is important to understand debris flow in the ocean for both environmental research and international relations. In this study, tsunami debris was monitored by satellite remote sensing. As a first step, we propose a method for identifying debris floating on turbid sea areas through thin clouds using two-dimensional scatter diagrams for MODIS spectral bands. Characteristic regions in the images are effectively separated by using the scatter diagram to identify six regions (land, coastal areas, debris, cloud, turbid sea, and clear sea). We report initial results of monitoring debris floating in the Pacific Ocean.

8525-40, Session PSWed

Optical remote sensing technique for monitoring of water basins
Victor I. Titov, Institute of Applied Physics (Russian Federation)

Optical remote sensing technique for monitoring of water basins including measurements of energy spectra of surface waves, kinematic characteristics of long surface waves and swells, near surface wind field investigation, oil slicks detection from ship, airplane or shore was developed.

The energy spectra of short waves are obtained in real time by spectral analysis of sea surface image with spectral analyzer operating under no coherent light. But previous measurements of spectra had relative characters. The technique for retrieval, there has a value of wave spectra is proposed. Preliminary model of two dimensional spectra of gravity - capillary waves for various winds derived from spectra of sea surface images is presented.

The spectral-kinematics characteristics of long energy waves are determined from optical RTI images (range-time-intensity images) constructed from optical profiles of sea surface. It is possible to form RTI images with range from some hundreds meters to kilometers depending on spatial resolution needed. The original device for recoding of RTI images using the linear array of CCD-photodiodes is created.

The principles of retrieval of spectral-kinematics characteristics of surface waves from RTI images are developed and method for formation of RTI images permitted to remove influence of ships roll is proposed. The method for retrieval long wave's field including swells and waves caused by local wind by optical RTI images derived from the ship is presented.

The method for detection and analysis of manifestations of near surface wind inhomogeneous such as wind front, eddy and so on, on sea images was developed.

One from directions of our work is investigation of oil slicks by optical technique.

The optical features of oil slicks derived in laboratory and natural conditions, variations of wave spectra in oil slicks are presented. The complex of optical devices may be used from shore or ship for monitoring of water basins in real time.

8525-41, Session PSWed

Wave effects on the retrieved wind field from the ASCAT scatterometer
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The scatterometer is a kind of non-nadir real aperture radar (RAR), which can estimate the wind field from the sea surface roughness induced by the wind field. The wind field is retrieved by the iterative calculation from geophysical model function (GMF). Based on the multi-scale scattering model, both wind wave and swell wave modulate the sea surface roughness. Typical GMF mainly consider the wind wave effects on roughness but lacks of the swell wave. This paper tries to find the wave effects on wind retrieval in cases of wind or swell dominated wave from the synchronous scatterometer and buoy data. The wind field data used in this paper are collected from Metop's Advanced Scatterometer (ASCAT) and buoy of NDBC. All wind speed data are converted into the 10 m blowing height above the sea surface. Besides the wind field, the buoy also provides the synchronous significant wave height (swh). Results show that the swh plays an important role in the wind speed retrieval in case of swell wave. When the swh be lower than 1.5 m, there is almost no significant error. When the swh be higher than 1.5 m, there is 10 m error approximated in case of wind wave. There is a good correlation between the buoy and ASCAT and a root mean square error (rmse) of 0.8 m.

8525-42, Session PSWed

Image feature analysis of Taiwan Bank sand wave group based on HJ-1 satellites remote sensing images
Huaguo Zhang, The Second Institute of Oceanography, SOA (China)

HJ-1A and HJ-1B, named as HJ-1, are two available satellites in the autonomy of the satellite constellation for disaster reduction in China. The spatial resolution of HJ-1 satellites is 30m, and their swaths are
360 km. The two satellites working together have great capability to detect very high coverage. Therefore, HJ-1 satellites have a very wide range of applications, including ocean applications. The sun glitter is a phenomenon very common in the HJ-1 satellites remote sensing images. In normal ocean remote sensing applications, the remote sensing images with sun glitter are considered as pollution images. However, the remote sensing images with sun glitter have a good application potential for some special ocean phenomena such as: ship trails, submarine topography and internal wave.

This paper is to analyze image features of the shallow sea topographic information on the HJ-1 satellites remote sensing images in Taiwan Banks as an example. Then the imaging conditions and mechanism, detection method of shallow sea topographic information are discussed. The results showed that:

(1) The sand wave group of entire Taiwan Banks can almost be detected in the two HJ-1 satellites remote sensing images. However, there are two types of image features because of the differences in sand wave stripes of the sand ridges, bright stripes and dark stripes. The two types of stripes may appear in one remote sensing image, even they are adjacent each other.

(2) Sun elevation angle and azimuth are the main conditions for sand wave group imaged in HJ-1 satellites images, which is mainly reflected in the image season. The Taiwan banks sand wave group is mainly found in the months from April to August each year, but not found in other months. June and August are the two best months for monitoring the Taiwan banks sand wave group.

(3) The application values of the remote sensing images with sun glitter are discussed. The most important application is to detect the depth of sand wave quantitatively. Then, HJ-1 satellites with high dynamic coverage are proper to monitoring the sand wave motion, tracking and monitoring of the long time of sand wave group in Taiwan Banks. Therefore, Remote sensing images with sun glitter from HJ-1 satellites are the important data source for monitoring and research in Taiwan Banks.

8525-43, Session PSWed

Relationship between the Zhejiang Coastal Upwelling and red tides in the East China Sea
Xiulin Lou, Aiqing Shi, Qingmei Xiao, Huaguo Zhang, Lihong Li, The Second Institute of Oceanography, SOA (China)

Upwelling water carries nutrients from deeper layer to surface layer and promotes the growth of planktons. The Zhejiang Coastal Waters in the East China Sea have the greatest one hour abundance, and also a high frequency area of red tides in China seas. In this article, relationship between the Zhejiang Coastal Upwelling and red tides in Zhejiang coast was studied with EOS MODIS imagery. Three years of sea-surface temperature (SST) images in summer from 2007 to 2009 were selected and processed to measure and monitor the coastal upwelling. And a total of 99 red tide events occurred during 2009 were selected and processed to measure and monitor the upwelling water. The coastal upwelling. And a total of 99 red tide events occurred during 2009 were selected and processed to measure and monitor the upwelling water.

8525-44, Session PSWed

Data processing of airborne infrared remote sensing for monitoring thermal discharge drained from nuclear plant
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Along with the nuclear power policy of accelerated development in China, the quantity of nuclear plants and machine sets increases quickly. As a result the environment influence of thermal discharge will be a problem that can’t be slid over.

At the end of 2007 and 2009, two airborne thermal discharge monitoring experiment have been carried out by making use of MAMS, a marine multi-spectral scanner. And experimental subject was sea area near Qin Shan nuclear plant. This paper briefly introduces the related specification and function of MAMS instrument, and decrypts design and process of the airborne remote sensing experiment. Then we will focus on some important steps for processing to solving some problems brought by infrared sensor. Among them, aiming at removing stripes phenomenon caused by black body, many methods including least square fitting, Chebyshev fitting, Spline fitting, Butterworth filter and Savitzky-Golay filter have been tested. Finally Savitzky-Golay filter provided the best result and the remote sensing on a base of thermal infrared monitoring technique told us that thermal discharge of Qin Shan nuclear plant was controlled in a small scope, never breaching national water quality standard.

8525-45, Session PSWed

A 15-year time series of photosynthetically available radiation over the world oceans from SeaWiFS and MODIS data
Robert J. Frouin, John McPherson, Kyozo Ueyoshi, Univ. of California, San Diego (United States); Bryan A. Franz, NASA Goddard Space Flight Ctr. (United States)

A global, 15-year record of photo-synthetically available radiation (PAR) at the ocean surface (9-km resolution) has been generated from SeaWiFS, MODIS-Aqua, and MODIS-Terra data. The PAR values are essentially obtained by subtracting from the solar irradiance at the top of the atmosphere (known) the solar energy reflected by the ocean-atmosphere system (satellite-derived) and absorbed by the atmosphere (modeled). Observations by individual instruments, combinations of two instruments, and three instruments are considered in the calculations. Spatial and temporal biases between estimates from one, two, or three instruments are determined and corrected, resulting in a consistent time series for variability studies. Uncertainties are quantified on daily, weekly, and monthly time scales for the various instrument combinations from comparisons with in situ measurements. Modes of seasonal and non-seasonal variability are investigated, and the correlative behavior of PAR, sea surface temperature, and chlorophyll concentration is examined. PAR monitoring will continue with current and future satellite ocean-color sensors, and the methodology will be extended to generating UV-A and UV-B irradiance.

8525-46, Session PSWed

Spectral response of the coral rubber, living corals and dead corals: study case on the Spermonde archipelago, Indonesia
Nurjannah Nurdin, Hasanuddin Univ. (Indonesia); Teruhisa Komatsu, The Univ. of Tokyo (Japan); Hiroya Yamano, National Institute for Environmental Studies (Japan); Gulam Arafat, Chair Rani, M. As Akbar, Hasanuddin Univ. (Indonesia)

Coral reefs play important ecological services such as providing foods, biodiversity, nutrient recycling etc. for human society. On the other hand, they are threatened by human impacts such as illegal fishing and environmental changes such as the rise of sea water temperature and sea level due to global warming. Thus it is very important to monitor spatial distributions of coral reefs and related habitats such as coral rubber, dead coral, bleached corals, seagrass, etc. Hyperspectral data, in particular, offer high potential for characterizing and mapping coral reefs because of their capability to identify individual reef components based on their detailed spectral response. We studied the optical properties by measuring in situ spectra of living corals, dead coral and coral rubber covered with algae. Study site was selected in Spermonde Archipelago, South Sulawesi, Indonesia because this area is included in the highest diversity of corals in the world named as Coral Triangle, which is recognized as the global centre of marine biodiversity and a global priority for conservation. Cluster analysis and ANOVA support that distinct differences in reflectance spectra among
categories existed. Common spectral characteristic of living corals, dead corals and coral rubber covered with algae was a reflectance maximum at 674 nm. Healthy corals, dead corals covered with algae and coral rubber covered with algae showed high similarity of spectral reflectance. It is estimated that this is due to photosynthetic pigments.

8525-48, Session PSWed

Did huge tsunami on 11 March 2011 impact seagrass bed distributions in Shizugawa Bay, Sanriku Coast, Japan?
Shuji Sasa, Shuhei Sawayama, Shingo Sakamoto, The Univ. of Tokyo (Japan); Ryo Tsumiyo, Genki Terauchi, Northwest Pacific Action Plan (Japan); Hiroshi Yagi, VisionTech Inc. (Japan); Teruhisa Komatsu, The Univ. of Tokyo (Japan)

In Japan, huge tsunami hit Sanriku coast on 11 March 2011 impacted not only human society but also coastal ecosystems. Seaweed beds are a very important habitat for abalone, commercially target species in this area, especially Shizugaw Bay. Thus, we mapped seaweed bed distribution by remote sensing in order to reveal impact by the tsunami on seaweed beds in Shizugawa Bay, GeoEye-1 multi-band imagery on 4 November 2009 before hit by the tsunami and that on 22 February 2012 after hit by the tsunami were analyzed to map seaweed bed distributions with a decision tree method. Since we have no sea-truth data before the tsunami, seaweed distribution including those of other habitats before hit by the tsunami were obtained by interviewing fishermen in 2012. Field survey was conducted to collect sea-truth data after the tsunami on 7 October 2011. Based on above-mentioned information, it was verified that the classification of habitats by remote sensing were sufficiently precise for detecting temporal change in seaweed bed distributions. After the tsunami, a part of seaweed bed was covered with soil by landslides caused by the tsunami and earthquakes on 11 March 2011. Seaweed beds were increased on debris and pebble deposited on sand bottom. The tsunami broke concrete breakwaters, entrained a large amount of rocks and pebble from land to the sea, and spread them in the bay to increase substrate suitable for attachment of seaweeds, especially Sargassum species.

8525-18, Session 4

Improved ocean-color remote sensing in the Arctic using the POLYMER algorithm
Robert J. Frouin, Pierre-Yves Deschamps, Univ. of California, San Diego (United States); Didier Ramon, Francois Steinmetz, Hygeos (France)

A flexible atmospheric correction algorithm, referred to as POLYMER (Steinmetz and al., 2011), has been applied to MERIS data acquired over the Chukchi and Beaufort Seas during ICESCAPE. This algorithm does not use a specific aerosol model, but fits the atmospheric reflectance by a polynomial with a non spectral term that accounts for any non spectral scattering (clouds, coarse aerosol mode) or reflection (glitter, whitecaps, small ice surfaces), a spectral term with a law in wavelength to the power -1 (fine aerosol mode), and a spectral term with a law in wavelength to the power -4 (molecular scattering, adjacency effects from clouds and white surfaces). The derived ocean properties, i.e., marine reflectance and chlorophyll concentration, are compared with those obtained with the standard MEGS algorithm. The POLYMER estimates are more realistic in regions affected by the ice environment, e.g., chlorophyll concentration is higher near the ice edge, and spatial coverage is substantially increased. Good retrievals are obtained in the presence of thin clouds, with ocean color features exhibiting spatial continuity from clear to cloudy regions. A first application to MODIS imagery is presented, revealing that POLYMER is robust when pixels are contaminated by sea ice.

8525-19, Session 4

Phytoplankton blooms in the South China Sea and the Western North Pacific subtropical gyre as observed by multiple satellite sensors: impact of aerosol, typhoon, and volcano
I.-I. Lin, Chun-Chi Lien, National Taiwan Univ. (Taiwan); George T. F. Wong, Academia Sinica (Taiwan); Chih-Wei Huang, National Taiwan Univ. (Taiwan) and Academia Sinica (Taiwan)

Western north Pacific Gyre and South China Sea are oligotrophic oceans. To better understand the global biogeochemical cycle and carbon fixation feedback of these oceans to climate, it is intriguing to explore phytoplankton blooms in these oligotrophic oceans. Using synergy of remote sensing data including ocean colour, aerosol, sea surface temperature, sea surface height anomaly, and ocean surface wind vectors, we analysis a number of different phytoplankton blooms observed. It was found that indeed significant phytoplankton blooms could occur and the nutrient sources include: volcanic eruption, Asian aerosols, ocean eddy, aerosols, and typhoons. Their impact on productivity and carbon fixation to climate are compared and discussed.

Reference:

8525-20, Session 4

Spatial and temporal variations of satellite-derived phytoplankton biomass in the Malacca Straits
Eko Siswanto, Univ. Teknologi Malaysia (Malaysia); Katsuji Tanaka, Japan International Research Ctr. for Agricultural Sciences (Japan)

A thirteen-year entire mission of SeaWiFS ocean color data were used to understand spatially long-term phytoplankton biomass (Chl-a) variation in the Malacca Straits (MS). Seasonal variation of SeaWiFS Chl-a in the MS was clearly observed showing high and low Chl-a during northeast monsoon (NEM) and southwest monsoon (SWM), respectively, but no long-term trend was observed. An offshore extension of high Chl-a from Peninsular Malaysia was clearly observed in the northern part of MS during NEM (November - January) which was accompanied by low AVHRR sea surface temperature (SST). Strong wind during NEM as revealed by QuickScat seemed to be a responsible forcing factor underlying surface cooling and Chl-a increase during NEM. The NEM strong wind intensified water column mixing and hence enhanced the entrainment of nutrient-rich, cold deep water into the surface layer. This increase of nutrients would stimulate phytoplankton growth resulting an offshore extension of high Chl-a. Unlike in the northern part of MS, SeaWiFS Chl-a in the middle and southern parts of MS showed long-term increases which were also accompanied by long-term decrease of AVHRR SST. Such a long-term increase in SeaWiFS Chl-a however had to be interpreted with caution, especially in the southern part of MS, because; their shallow and narrow areas allowed bottom sediment to be easily re-suspended; and rivers from Malaysia and Indonesia might also load suspended sediment (SS) into the MS which ultimately led to incorrect SeaWiFS high Chl-a retrieval.
Retrieval of Chlorophyll-a using satellite and ground spectral data in Japanese and Sri Lankan water bodies

Dahanayakage Don G. Dahanayaka, Hideyuki Toonoka, Ibaraki Univ. (Japan); Jayanthi Wijeyaratne, Univ. of Kelaniya (Sri Lanka); Atsushi Minato, Satoru Ozawa, Ibaraki Univ. (Japan)

The suitability of the BSR112E spectrometer and ASTER satellite data for monitoring water quality in coastal waters of Sri Lanka and inland waters of Japan was tested in November 2010 - March 2012. In-situ Chlorophyll-a (Chl-a), turbidity, total suspended solid, secchi depth and reflectance data were measured with ASTER overpass at Negombo estuary, Trincomalee bay, Puttalam and Chilaw lagoons in Sri Lanka and Lake Senba and Lake Kasumigaura in Japan. ASTER based Chl-a retrieval algorithms were developed with support in-situ Chl-a and MODIS OC3 Chl-a. The original MODIS Chl-a and the in-situ Chl-a are regressively analyzed for determination of a MODIS Chl-a correction equation in Sri Lankan water bodies because it may overestimate in tropical coastal waters. Then, three ASTER VNIR band ratios are compared for correlation with the corrected MODIS Chl-a and in-situ Chl-a. Finally, the regression equation of the ASTER band ratio with highest correlation which was B1/B2 is used for generation of high-resolution Chl-a distribution maps. Significant correlation between the ratio of the reflectance peak at 705 nm and the Chl-a absorption at 678 nm and in-situ Chl-a content was observed and these reflectance ratio used to derive algorithm based on the spectrometric method. Proposed algorithms were successfully able to determine localized environmental effects in study areas. ASTER based high resolution Chl-a distribution maps could be derived more precisely by further correction of the algorithms, which will be useful in mitigate impacts of the environment change in those coastal and inland water environments.

Remote sensing application for Sardinella lemuru assessment: a case study of the south waters of Malang Regency, East Java, Indonesia

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The assessment of lemuru fish (Sardinella lemuru) using remote sensing and Geographical Information System (GIS) has provided preliminary information on the habitat of lemuru fish at the South waters of Malang Regency, Indonesia. Lemuru fish catch data, mangrove mapping, Sea Surface Temperature (SST) and chlorophyll-a concentration derived from MODIS/Aqua images have been used in this study. The average of SST during the study was 28.1 OC, the highest average was on December and August was the lowest. The average of chlorophyll-a concentration was 0.55 mg/m3, July was the highest and the lowest concentration of chlorophyll-a was on March. Most of the lemuru fish migrated to the west part of Malang waters during northwest monsoon (December-February), and moved toward eastern part during transitional (March-April-May). In contrast, on the southeast monsoon (June-August), lemuru spread across Malang waters. Habitat suitability of lemuru around coastal waters of Malang Regency related to their migration has different criteria for each month depend on the oceanographic factors and primary productivity. Based on the levels of habitat suitability, lemuru predicted to spawn on June. Sumbermanjing area was the most suitable area (72.39%). Lemuru moved away from Malang waters during transitional until the beginning of northwest monsoon. Primary productivity in coastal waters around Sumbermanjing increased in the southeast monsoon. It represented by high Chla (0.7 mg/m3) in the northwestern monsoon and increased reaches 3 mg/m3 in the southeast monsoon on July. It was followed by the increasing of lemuru catch.
Coral reef habitats mapping of Spermonde Archipelago using remote sensing, compared with in situ survey of fish abundance

Shuhei Sawayama, Teruhisa Komatsu, The Univ. of Tokyo (Japan); Nurjannah Nurdin, Hasanuddin Univ. (Indonesia)

Coral reefs worldwide are now facing so great crises due to various impacts that monitoring and managing their resources are urgently required. In order to understand the ecological status of coral reefs and the fish stocks in their habitats and to find out indicator fish species for specific habitats, seabed habitats mapping using remote sensing and in situ fish survey were conducted in Spermonde Archipelago, Indonesia. The ALOS AVNIR-2 imagery on 14 October 2010 was analyzed to classify its pixels into 4 habitats (i.e., Live-coral, Dead-coral, Seagrass-bed and Sand-rubble). Groundtruth data were obtained using a towed video camera and a sidescan sonar in May and June 2011. Depth-Invariant indices (DI-indices) were calculated to correct the water column attenuation effects and applied for maximum-likelihood classification as well as original 3-bands radiance values. Unexpectedly, the resulted accuracy of the mapping by DI-indices didn’t differ significantly from that by radiance values ($r=0.05$), approximately 65% in Tau-coefficient. In the same period, the distribution of butterflyfish was estimated using visual fish survey was conducted at 18 sites, counting 12 defined fish groups by snorkeling. Spearman’s rank correlation efficient between the ratio of each habitat classified by DI-indices and the abundance of every fish group was calculated. As a result, the abundance of 5 fish groups correlated with specific habitats significantly, including butterflyfish with Live-coral (80% in user-accuracy). This result supported the thesis that butterflyfish is the good indicator of healthy corals, suggesting the meaningfulness in studying the relationships between fish abundance and the spatial distribution of habitats in large-scale.

Mapping seaweed forests with IKONOS image based on bottom surface reflectance

Tatsuyuki Sagawa, Remote Sensing Technology Center of Japan (Japan); Atsuko Mikami, Teruhisa Komatsu, Atmosphere and Ocean Research Institute, The University of Tokyo (Japan); Masakazu N Aoki, Graduate School of Agricultural Science, Tohoku University (Japan)

Seaweed forests are important habitat for many fishery species. However, decrease in seaweed forests is reported in all over Japan due to unknown reasons. Mapping and monitoring seaweed forest distribution is necessary for understanding their present status and taking measures for their conservation.

Traditional diving visual observation is not efficient for large scale mapping. Thus, alternative method is required. Satellite remote sensing is one of the noteworthy methods, but so far, only a few studies have been conducted. There are two main problems about mapping seaweed forests by remote sensing. The first one is a difficulty to collect field truth data. The second one is a light attenuation effect in seawater which makes analysis more difficult. We applied an efficient method to overcome these two problems.

We selected the coast off Shimoda in Izu peninsula, Japan as a study area. An IKONOS satellite image was used for analysis because its high spatial and radiometric resolutions are practical for seaweed mapping. We measured spectral reflectance profiles of seaweed and substratum in the study area. The result revealed effective wavelength bands for distinguishing seaweeds and substratum. Truth data for satellite image analysis and evaluation were collected in the field using boat and aquatic video camera. This method allowed us to collect many truth data in short time.

Satellite image analysis was conducted using radiometric correction about water column and maximum likelihood classification method. The overall accuracy using error matrix reached 97%. This result indicates usefulness of this method for seaweed forest mapping.

Comparison of contrast improvement of extracted laver cultivation area using parameters derived from polarimetric SAR data

Mitsunobu Sugimoto, Kazuo Ouchi, Yasuhiro Nakamura, National Defense Academy (Japan)

In this study, we investigated contrast improvement of extracted laver cultivation area using various parameters that can be calculated by polarimetric synthetic aperture radar (POLSAR) data for the purpose of extracting the target area more effectively and deciding suitable methods within the limitation of available polarization. Every year starting from October, laver cultivation nets are placed at approximately 10-20 cm below the sea surface with supporting floats with laver spores attached to the nets. grow during winter, and the grown laver is harvested in next April. Through this process, the nets are sometimes placed above the sea surface to promote photosynthesis. When the nets are placed underwater, the areas become effectively shallow water, and small-scale waves, that are the principal scatterers, are damped, resulting in reduced radar backscatter. Each parameter, derived from Pauli decomposition, eigenvalue analysis, coherence analysis, and the four-component scattering power decomposition (4-CSPD) with/without rotation, has distinctive characteristics and react to different backscatterers differently. Comparison was made using those parameters and experimental results showed that the contrast improved using multi polarization data than using single polarization data. We showed that entropy performs better among dual polarization methods, and surface scattering calculated from 4-CSPD shows higher contrast than any other parameters from quad polarization data. This study could also be applied to detect polluted area caused by tanker accident or offshore-oil disaster since spilled oil on the sea has similar physical characteristics to laver cultivation area.

Small leaf seagrass bed detection in turbid water using ALOS AVNIR 2 in Lap An lagoon, Thua Thien Hue, Vietnam

Ha N. Thang, Kunihiko Yoshino, Univ. of Tsukuba (Japan); Tong P. H. Son, Institute of Oceanography (Viet Nam)

Seagrass bed play a critical role in the ecological functions of the coastal zones. They assist the nursery and juvenile habitat to the fisheries, stabilize the sediment and provide a direct food for dugongs and green turtles. Lap An is the semi-enclosed lagoon in the South of Thua Thien Hue province with the large area of mangrove and seagrass. This lagoon support significantly to the local aquaculture, and the highly important nursery for economical fisheries.

The objective of this research is to detect the distribution of the small leaf seagrass in the condition of turbid water. ALOS AVNIR 2 data was applied to detect the scatter small patches of seagrass. Water column correction, the decision tree technique and the ground control points in the fields were exerted to enhance the classification accuracy of the study.

This research may contribute a new approach for detecting the seagrass meadows, toward the better integrated management of the coastal zones.

Mangrove analysis using ALOS imagery in Hai Phong City, Vietnam

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Mangroves appear in the inter-tidal zones along the coast in most tropical and semi-tropical countries. They play a vital role in coastal
zones and can defend against the impacts of tsunamis. Nevertheless, these forests are under severe threat because of high population growth, weak governance, poor planning, as well as uncoordinated economic development. Hai Phong city is located on the Northern coast of Vietnam where the mangroves are distributed between zone I and zone II among the four mangrove zones in Vietnam. This city is vulnerable to rising sea levels and tropical cyclones, which are forecasted to become more severe in coming next decades. The objectives of this research were to analyze the current status of mangroves using different ALOS sensors in Hai Phong, Vietnam in 2010 and compare the accuracy of the post satellite image processing of ALOS imagery in mapping mangroves. A combination of object-based and supervised classification was used to generate the land cover maps. The results of this research indicate that the total area of mangrove was approximately 3,534 hectares and mangrove is present in the five coastal districts in Hai Phong. The findings of this research showed that ALOS AVIR-2 provides better accuracy than ALOS PALSAR. This research indicates the potential of utilizing image segmentation associated with supervised method for both optical and SAR images to map mangrove forests in coastal zones.

8525-32, Session 6
Evaluation of classification techniques for benthic habitat mapping
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The Coral ecosystem is sensitive to environmental changes thus accurate, up to date information on their status is critical for effective management of these important marine resources. However, environmental conditions of these habitats are challenging to map due to their remoteness, extent and costs of monitoring. In this research, the capabilities of satellite remote sensing techniques combined with in situ data were assessed to generate coral habitat map of Lang Tengah Island, Terengganu, Malaysia. Several classification techniques were utilized in identifying coral distribution to assess their ability to map different type of benthic habitat associated with coral reefs. Five classifiers were used to classify the study area mainly, Parallelepiped, Minimum distance, Maximum likelihood, Fisher and K-Nearest Neighbor. Using the same training data sets to evaluate their effectiveness, results from the classification shows that each method produced different accuracy based on bottom type. Utilizing the strength of each classifier this study was able to increase per class accuracy of the habitat map through several image processing techniques namely majority voting, simple averaging and maximum combination. Results show that by utilizing these ensemble techniques for classifying benthic habitat the accuracy produced was higher than conventional supervised techniques.

8525-33, Session 6
Impact of huge tsunami in March 2011 on seaweed bed distributions in Shizugawa Bay, Sanriku Coast, revealed by remote sensing
Shingo Sakamoto, Shuhel Sawayama, Shuji Sasa, The Univ. of Tokyo (Japan); Ryo Tsujimoto, Genki Terauchi, Northwest Pacific Action Plan (Japan); Hiroshi Yagi, VisionTech Inc. (Japan); Teruhisa Komatsu, The Univ. of Tokyo (Japan)
Seagrass beds play important roles for coastal ecosystem such as spawning and nursery grounds of fish and mollusks, and provide us important ecological services. On 11 March 2011, huge tsunami hit Sanriku coast after the big earthquakes occurred in Northwestern Pacific Ocean. Seagrass beds were damaged at the bottom in Shizugawa Bay, Sanriku coast, before the tsunami in 2011. Thus, remote sensing research was conducted to evaluate impact of the tsunami on seagrass bed in Shizugawa Bay, Sanriku coast. GeoEye-1 multispectral imagery taken on 4 November 2009 and 22 February 2012 were analyzed to map seagrass beds. Analysis of the former imagery showed seagrass bed was distributed in sheltered bottom against waves along the coast corresponding to seagrass distribution obtained through inquiry to fishermen on seagrass bed distribution before the tsunami. Analysis of the latter imagery indicated that seagrass bed distribution in February 2012 was less than in November 2009. Seagrass beds in the bay head disappeared while some seagrass beds remained behind the points along the north coast. This was verified by the field survey conducted in October 2011. Because the tsunami wave is reflected by both sides of the bay, it advances with refracting into the bay head. Its energy is concentrated there and removes seagrass with substrate. On the other hand, the tsunami higher than 12 m could not completely destroy seagrass beds due to topographic effect protecting seagrass from strong force by the tsunami.

8525-34, Session 6
Can ALOS-3/HISUI detect seaweed beds more precisely than ALOS/AVNIR-2?
Tatsuyuki Sagawa, Tomohiro Watanabe, Remote Sensing Technology Ctr. of Japan (Japan); Akira Watanuki, Alpha Hydraulic Engineering Co. Ltd. (Japan); Heiichiro Kamiumi, Japan Aerospace Exploration Agency (Japan); Teruhisa Komatsu, The Univ. of Tokyo (Japan)
Hyperspectral Imager Suite (HISUI) is Japanese future spaceborne hyperspectral sensor system. It will be launched in 2015 or later as one of mission instruments onboard JAXA's Advanced Land Observation Satellite 3 (ALOS-3). HISUI will consist of a hyperspectral imager and a multispectral imager with 30 m and 5 m spatial resolution and 30 km and 90 km swath, respectively. In order to characterize capability to detect seaweed beds of HISUI multispectral data with 5 m spatial resolution, we compared classification results between ALOS/AVNIR-2 with spatial resolution of 10 m and simulation data of HISUI produced from WorldView-2 multiband data. Study site was selected in Oita Prefecture in Kyushu Island, Japan, where seaweed beds were broadly distributed along the coast. We used AVNIR2 data taken on 20 February 2007 and simulation data produced from WorldView-2 taken on 18 April 2010. Supervised and unsupervised classifications were applied to these data sets. Miss-classification of analysis using AVNIR-2 was identified in deep waters in offshore waters. Since radiometric resolution of AVNIR-2 is 8 bits, it is considered that low radiometric resolution causes miss-classification. Spatial resolution of HISUI multiband data that is 5 m makes boarders of seaweed beds more clear. Precision of classification using HISUI simulation data was about 90% and 10% higher than that using AVNIR-2. Thus HISUI multiband data are suitable for mapping seaweed beds in coastal waters.

8525-47, Session 6
Marine Habitat Mapping: Using ALOS AVNIR-2 Satellite Image for Seagrass Beds at Rabbit (Koh Tonsay) Island, Cambodia
Sophanly Phauk, Royal Univ. of Phnom Penh (Cambodia); Teruhisa Komatsu, The Univ. of Tokyo (Japan); Thidarat Noiraksa, Burapha Univ. (Thailand)
Coastline is stretched along the Gulf of Thailand including 64 islands in Cambodia. Coastal habitats such as mangrove forests, coral reefs and seagrass beds still remain pristine and unknown. Seagrass beds support biodiversity as an important habitat and supply economically valuable fisheries production. They also play important environmental roles such as mitigating climate change through retaining large amounts of carbon with photosynthesis. However, global status of these seagrass beds is poorly researched and documented. Sustainable development of coastal zones needs conservation of seagrass beds providing important ecological services. To conserve seagrass beds, it is indispensable to know spatial distributions of seagrass beds. Thus, mapping seagrass beds is needed in Cambodia that has started economical development. ALOS AVNIR-2 with high spatial resolution (10x10m) probably offers good description of seagrass beds. For commencement of mapping research, we studied a capacity of AVNIR2 images to map seagrass beds in Cambodia. Since Rabbit Island, which is located 4.6 km south of Kep province with an area of 2 km2, is famous of seagrass distribution, it was selected as a study site. Seagrass beds were mapped with use of ALOS AVNIR2 images taken in different seasons and years between 2007 and 2010. Ground truth survey was conducted in 2012. Analysis of ALOS AVNIR2
images could show not only broad spatial distribution of seagrass beds around the island but also significant change of seagrass beds at southeastern part of the island. These results indicate that seagrass beds can be mapped by using ALOS AVNIR2.

8525-49, Session 6

Using remote sensing technique for analyzing temporal changes of seagrass beds by human impacts in waters of Cam Ranh Bay, Vietnam

Phan Minh-Thu, Tong Phuoc Hoang-Son, Institute of Oceanography (Viet Nam); Teruhisa Komatsu, The Univ. of Tokyo (Japan)

Seagrass beds are high are highly diverse and productive ecosystems, but they have been degraded under high pressures of human activities. Combining depth-invariance index methods and ground-truthing method, distribution of seagrass beds in Cam Ranh Bay was identified by analyses of multi-remote sensing images, such as LANDSAT, SPOT and ALOS AVNIR-2. Seagrass beds were coverage of 1178 ha. However, the seagrass beds were being degraded by illegal fishing methods, aquaculture, industry and living domestics. The reducing ratio of seagrass coverage has been increased in recent years. The depth-invariance index method would help to detect the areas of seagrass beds, but this method should be combined with field trip and absorption library methods to increase the ratio of accuracy. Finally maps of the status and changes of seagrass beds could help to integrate in the sustainable development of economics and protected natural resources.
8526-1, Session 1

Conductive-cooled 2-micron laser development for wind and CO₂ measurements

Kohei Mizutani, Shokenu Ishii, Yasui Motoaki, Toshikazu Itabe, National Institute of Information and Communications Technology (Japan); Atsushi Sato, Kazuhiro Asai, Tohoku Institute of Technology (Japan); Hirotake Fukuoka, Hamamatsu Photonics K.K. (Japan); Takayoshi Ishikawa, Nippon Aleph Corp. (Japan)

We are developing two types of 2-micron conductive-cooled lasers for wind and CO₂ measurements. One type of lasers is side pumped Tm:Ho:YLF laser operated at 20-40Hz. The laser rod is cooled down to -80°C in a vacuum container. Ho:YLF laser end-pumped by Tm:fiber laser is another type which will be operated at high repetition rate of 200-300 Hz in normal temperature. These lasers are conductive-cooled, solid-state and eye-safe. Then, these are suitable for space applications.

8526-2, Session 1

1.5-µm high-average power laser amplifier using an Er,Yb:glass planar waveguide for coherent Doppler lidar

Takeshi Sakimura, Yojiro Watanebe, Toshiyuki Ando, Shumpei Kameyama, Kimio Asaka, Hisamichi Tanaka, Takayuki Yanagisawa, Yoshihito Hirano, Mitsubishi Electric Corp. (Japan); Hamaki Inokuchi, Japan Aerospace Exploration Agency (Japan)

We have developed a 1.5-µm eye-safe wavelength high-average power laser amplifier using Er,Yb:glass planar waveguide for a coherent Doppler LIDAR. Large cooling surface of the planar waveguide realized high-average power pumping for Er,Yb:glass which has low thermal fracture limit. Nonlinear effects threshold is controlled by the waveguide thickness and the beam width of the planar direction. Multi-bounce optical path configuration and high-intensity output high-average power of the signal was 7.6W with the amplified gain of more than 20 dB. This amplifier is suitable for a coherent Doppler LIDAR to enhance the long range measurement.

8526-3, Session 1

All-solid-state rapidly tunable coherent 6-10 µm light source for lidar environmental sensing

Norihito Saito, Masaki Umoto, Takayuki Tomida, Utaho Takagi, Satoshi Wada, RIKEN (Japan)

We report on an all-solid-state rapidly tunable pulsed coherent 6-10 µm light source achieved in an optical parametric oscillator (OPO) pumped with an electronically tuned Cr:ZnSe laser and its application to lidar remote sensing for environmental detection. The Cr:ZnSe laser was pumped with a Tm:YAG laser operated at a repetition rate of 10 Hz. An acousto-optic tunable filter as a tuning element was used in the Cr:ZnSe laser cavity. We obtained the tuning range from 2.12 to 2.67 µm in the Cr:ZnSe laser with change in radio frequency from 45.5 to 36.0 MHz. The wavelength was tuned every pulse shot at an operated frequency in the Tm:YAG laser. The Cr:ZnSe laser was used as a pump source in an OPO. A nonlinear optical crystal was fixed at a phase-matched angle in the OPO cavity. The signal and idler waves emitted from the OPO were rapidly tuned in the range from 6 to 10 µm by tuning the Cr:ZnSe laser without mechanical rotation of dispersive optical elements. A maximum output energy of 10 mJ can be expected near 7.0 µm. We designed a lidar system using the 6-10 µm light source and a telescope with a primary mirror of 50 cm and a high-efficient HgCdTe detector. The lidar system would be a valuable system in the measurement of chemical agents in the 100-300 m.

8526-4, Session 1

Development of a simultaneous dual-wavelength Q-switched Nd:YAG laser at 1064 and 1319 nm

Atsushi Sato, Takumi Abe, Shimpei Okubo, Kazuhiro Asai, Tohoku Institute of Technology (Japan); Nobuo Sugimoto, National Institute for Environmental Studies (Japan); Shokenu Ishii, Kohei Mizutani, National Institute of Information and Communications Technology (Japan)

Accurate measurements of a canopy height and a normalized difference vegetation index (NDVI) are of great interest to studies on Earth’s carbon balance. Lidar remote sensing is one of the most promising techniques for observations of vegetation information. A dual-wavelength Q-switched Nd:YAG laser operating at 1064 and 1319 nm is useful as a light source for simultaneous lidar observations of the canopy height and the NDVI. A fundamental laser at 1064 nm is suitable to the canopy height measurements, and is corresponding to the near-infrared band in the NDVI measurement. On the other hand, second-harmonic generation at 1319 nm can produce laser pulses at 660 nm, which is corresponding to the red band in the NDVI measurement. In this study, a simultaneous dual-wavelength Q-switched Nd:YAG laser with a common laser pump head has been developed. Because a common upper laser manifold, the Nd 4F3/2, is used in dual-wavelength lasing at 1064 and 1319 nm, the energy stored in the upper laser manifold is shared between these two wavelengths. Simultaneous dual-wavelength lasing was achieved by adjusting an interval between two Q-switch trigger times and by optimizing the resonator designs for both wavelengths. When two Q-switched pulses started simultaneously, pulse widths at 1064 and 1319 nm were 28 and 65 ns, respectively. The pulse-to-pulse amplitude stability at each wavelength exhibited at most +/-20% fluctuation about the mean. As a result, Q-switched pulse energies of 8.4mJ and 9.2mJ were obtained at 1064 and 1319 nm, respectively.

8526-44, Session 1

Development of laser/lidar technologies for enabling NASA earth science measurements (Keynote Presentation)

George J. Komar, NASA Headquarters (United States)

No Abstract Available

8526-5, Session 2

Study of fluorescence of atmospheric aerosols using a lidar spectrometer

Nobuo Sugimoto, National Institute for Environmental Studies (Japan); Zhongwei Huang, Lanzhou Univ. (China); Tomoaki Nishizawa, Ichiro Matsu, National Institute for Environmental...
A lidar measuring fluorescence from atmospheric aerosols was constructed with a third harmonic Nd:YAG laser, a 1-m diameter telescope, and a 32-channel time-resolved photon counting spectrometer system (a 120-mm focal length spectrometer with a Licel Multispectral Lidar Detector). The fluorescence from aerosols in the spectral range from 420nm to 520nm was studied with the excitation at 355nm. A broad fluorescence of aerosols was observed in this spectral region. However, the peaks in the spectrum previously reported were not found so far. The intensity of the broad fluorescence was dependent on air mass. Relationships between the fluorescence intensity (normalized by the nitrogen Raman scattering intensity) and the aerosol extinction coefficient, the particle depolarization ratio (and aerosol type) were studied.

8526-7, Session 2
Application of lidar and optical data for oil palm plantation management in Malaysia
Helmi Zulhaidi Mohd Shafri, Mohd Hasmadi Ismail, Univ. Putra Malaysia (Malaysia); Mohamad Khairil Mohamad Razi, Felda Technoplant Sdn Bhd (Malaysia); Mohd Izuzzadin Anuar, Univ. Putra Malaysia (Malaysia); Abdul Rahman Ahmad. FELDA (Malaysia)

Proper oil palm plantation management is crucial for Malaysia as the country depends heavily on palm oil as a major source of national income. Precision agriculture is considered as one of the approaches that can be adopted to improve plantation practices for plantation managers such as the government-owned FELDA. However, currently the implementation of precision agriculture based on remote sensing and GIS is still lacking. This study explores the potential of the use of Lidar and optical remote sensing data for plantation road and terrain planning for planting purposes. Traditional approaches use land surveying techniques that are time consuming and costly for vast plantation areas. The first ever airborne Lidar and optical remote sensing survey for oil palm plantation was carried out in early 2012 to test its feasibility. Preliminary results show the efficiency of such technology in demanding engineering and agricultural requirements of oil palm plantation. The most significant advantage of the approach is that it allows plantation managers to accurately plan the plantation road and determine the planting positions of new oil palm seedlings. Furthermore, this creates for the first time, digital database of oil palm estate and the airborne imagery can also be used for related activities such as oil palm tree inventory and detection of palm diseases. This work serves as the pioneer towards a more frequent application of Lidar and optical data for oil palm plantation in Malaysia.

8526-8, Session 2
Development of polarization optical particle counter to detect particle shape information
Hiroshi Kobayashi, Univ. of Yamanashi (Japan); Masahiko Hayashi, Fukuoka Univ. (Japan); Yoshinobu Nakura, Yamanashi Gijutsu Kobo (Japan); Takayuki Enomoto, Kauzhiiko Miura, Tokyo Univ. of Science (Japan); Hiroshi Takahashi, Yasuhito Igarashi, Meteorological Research Institute (Japan); Hiroaki Naoe, Japan Meteorological Agency (Japan); Tomoaki Nishizawa, Nobuo Sugimoto, National Institute for Environmental Studies (Japan)

Polarization optical particle counter (POPC) capable of measuring particle shape or sphericity was developed, which uses detection of polarization of light scattered by particles. Sensors that detected P and S polarization components are incorporated at scattering angle of 120° in addition to ordinary sensor located at the angle of 60°. The particle size is derived from the pulse height detected with the ordinary sensor. The size thresholds were determined by measurements of PSL standard particles. Polarization of particle is calculated as the ratio of S polarization component to the sum of all components. The POPC field observations were started in Fukuoka, Japan on 15 March 2012 and in Matsue, Japan on 28 February 2012. Air pollution with high particle number concentration was observed in Fukuoka on 11 April.

In that time, the particles with polarization lower than 0.3 constituted 90% of particles in the size range from 0.5 μm to 3 μm and 70-90% of those from 3 μm to 5 μm. Most of the atmospheric aerosol particles were consisted of spherical particles. Significant Asian dust transport was observed in Fukuoka on from 31 March to 1 April. The particles with polarization lower than 0.3 constituted 80% of those from 0.5 μm to 1 μm, 55-65% of those from 1 μm to 5μm. The increase of the ratio of non-spherical particles to all particles in Asian dust event was confirmed. The POPC thus is capable of measuring particle shape as well as size for each individual particle.

8526-9, Session 3
Range accuracy and simulation of lidar ranging system based on time-correlated single-photon counting
Weiji He, Yunfei Chen, Nanjing Univ. of Science & Technology (China); Yaoqin Cheng, Wei Cheng, Science and Technology on LLL Night Vision Lab. (China); Qian Chen, Nanjing Univ. of Science & Technology (China)

Geiger mode single-photon detectors and time-correlated single-photon counting techniques have been widely used in pulse ranging system and three-dimensional imaging systems. In this paper, a theoretical model of Lidar ranging system is established and the factors effect on the accuracy is considered. Based on statistical theory, the longitudinal spatial resolution is mainly determined by the echo signal intensity and the echo signal width. The echo signal width mainly includes the laser pulse width and the response width of the detection system. The latter is mainly depending on the timing jitter of the detector. We simulated the received echo waveform with Monte Carlo method based on the above factors and analyzed the error of range accuracy. The experimental lidar ranging system based on time-correlated single-photon counting was established in the lab and finally the experimental results are given to verify the system simulation.

8526-10, Session 3
Lie-EM-ICP algorithm: a novel frame for 2D shape registration
Chunxiao Shao, Shanghai Univ. (China); Chaomin Shen, East China Normal University (China); Yaxin Peng, Shihui Ying, Shanghai Univ. (China)

In this paper, a 2D shape registration algorithm for noisy and incomplete data is established by combining the Expectation Maximization (EM), Iterative Closest Point (ICP) method and Lie Group representation. First, the problem is formulated by a minimizing problem with two sets of variables: the point-to-point correspondence, and the transformation between two data sets. The conventional way for solving this model is by iterating alternatively the following two steps: 1) having the correspondence fixed, solve the transformation; and 2) having the transformation fixed, solve the correspondence. In the first step, to enhance the robustness of algorithm, EM algorithm is introduced to find the correspondence by a correspondence probability which covers the relationship of all points, instead of one-to-one closest correspondence in ICP. Then, the algorithm is designed by minimizing the energy functional by considering the correspondence as a random. Meanwhile, Lie group is used to parameterize transformation and a unified framework to design and analyze the registration algorithms is formed. Then, transformation is estimated easily by solving a quadratic programming. By iterating alternatively above two procedures, an approximate solution of transformation is calculated. The experimental results in 2D shape registration demonstrate that, compared with EM-ICP and Lie-ICP, our algorithm is more robust and accurate.
Using Er,Yb:glass planar waveguide. Recently, we have developed the high output power laser amplifier using Er,Yb:glass planar waveguide. After this development, we have developed the 1.5 µm coherent Doppler LIDAR using this laser amplifier. In this paper, we introduce this development and demonstrate of a long range wind sensing using the developed system. The system consists of the fiber-based pre-amplifier stage and the post-amplifier stage with the above mentioned amplifier using the planar waveguide. The output pulse has an energy of 1.4 mJ with a pulse repetition frequency of 4 kHz, in addition to a nearly diffraction limited beam quality. In the wind sensing, we demonstrate the measurable range of more than 30 km in addition to the stable system operation. To our knowledge, this is the longest measurable range demonstration for wind sensing coherent Doppler LIDARs.

8526-14, Session 4
A combined rotational-vibrational Raman lidar for profiling the atmospheric temperature, humidity, and aerosol of the troposphere
Yufeng Wang, Dengxin Hua, Huige Di, Shichun Li, Xi’an Univ. of Technology (China); Takao Kobayashi, Univ. of Fukui (Japan)

An UV combined rotational-vibrational Raman lidar system with high-resolution grating and narrow-band filter as spectroscopic system has been developed at Xi’an, China, for quantitative detection of atmospheric temperature, relative humidity and aerosol properties of the troposphere. The rotational Raman signals of nitrogen molecular (N2), the vibrational Raman signals of N2 and water vapor molecular (H2O) are used to retrieve the atmospheric temperature and water vapor density respectively. Aerosol extinction coefficient, backscattering coefficient, backscattering ratio and aerosol optical depth are retrieved by combining the vibrational Raman signal and Mie-Rayleigh signal. Continuous observations have been carried out at nighttime for water vapor and aerosols at Xi’an (34.233°N,108.911°E), the results clearly showed the relevance between the water vapor and aerosols by the Time-Height Indicator (THI) display. Furthermore, the seasonal variation of water vapor mixing ratio and aerosol optical depth were observed and analyzed by using their average monthly distribution by lidar for the first time over Xi’an, and those results of observation will provide useful scientific data for studying local climate change of Xi’an.

8526-16, Session 5
Global distribution of dust devil derived from CALIPSO lidar measurements
Jianping Huang, Jingjing Liu, Hongru Yan, Lanzhou Univ. (China); Yuhong Yi, Science Systems and Applications, Inc. (United States)

Dust emission is a small scale process that can have global consequences, such as cloud formation, anthropogenic carbon dioxide emission, snow albedo change, and land use change. Satellite remote sensing has revolutionized the study of dust transport, particularly at the regional and global scales important for climate analysis. However, knowledge of dust devil emissions is still very limited because their relatively small sources do not often produce plumes visible from space. The Cloud-Aerosol Lidar and Infrared Pathfinder Observations CALIPSO satellite carries a down-looking lidar that shoots a laser beam into the atmosphere providing continuous measurements of clouds, dust, and other aerosols along the satellite’s path. Data from these lidar measurements can yield new insight into the detection of dust devil emission. Here, we present an estimate of the global distribution of dust devil by using CALIPSO lidar measurements.

8526-17, Session 5
Remote sensing for physical geography from ISS by JEM-EUSO
Takayuki Tomida, Takayo Ogawa, Satoshi Wada, RIKEN (Japan); M. D. Rodriguez Frias, Univ. de Alcala (Spain); Andrii Neronov, ISDC Data Ctr. for Astrophysics (Switzerland)
Always, in the atmosphere of the earth we live in is a luminous phenomenon (Fluorescence by cosmic rays, lightning and aurora etc.) has been occurring.

JEM-EUSO (Extreme Universe Space Observatory onboard Japanese Experiment Module) experiment is the observation that aims to capture the luminous phenomenon in earth’s atmosphere from orbit. JEM-EUSO telescope observations have been using a Fresnel lens of the world’s largest.

The observation area (250km radius at the sea level) is extremely larger than the telescope installed on the ground to capture the luminous phenomenon.

The main target of EUSO is to capture the fluorescence emission caused by UHECR (Ultra-High-Energy Cosmic Ray). This way that is extremely large observation area for UHECR will be frontier for astronomical observation of charged particles for relatively near space (300Mpc).

Because JEM-EUSO observe fluorescence in the atmosphere of the earth from space, it is necessary to measure the state of the atmosphere (cloud cover and transparency in particular) for the calibration.

The infrared camera mounted on the JEM-EUSO is used to measurement of cloud coverage and cloud top height. For the atmospheric transparency measurement and calibration of the cloud top height, we use the LIDAR system using EUSO’s telescope and the laser.

It is also possible that in addition to this, to know the state of the atmosphere based on the background light captured by EUSO’s telescope. These measurements of atmospheric conditions for the observation of UHECRs is not only calibration data.

The atmospheric observation that covers the entire ground is the vital information in physical geography. Furthermore, it is possible to measure light emission by lightning or meteor that occur in the field of view during observation of darkness in the JEM-EUSO.

Expected by combining a lot of measurement, to understand of the earth and proceed further.

8526-18, Session 5

Particulate backscatter coefficient statistics of suspended particulate matter (coastal and open ocean) from CALIPSO

Yongxiang Hu, NASA Langley Research Ctr. (United States)

Particulate backscatter coefficient (Bbp) of suspended particulate matter is a parameter highly correlated to phytoplankton biomass and particulate organic carbon (POC) stocks. There is large uncertainty in Bbp estimated from ocean color measurements.

Bbp can be estimated from CALIPSO’s subsurface cross polarization lidar backscatter measurements. To derived Bbp from the CALIPSO measurements, we need extra information such as diffuse attenuation coefficient (Kd) derived from collocated ocean color observations. The study also benefited from large amount of ship based measurements of inherent optical properties (IOPs) that help us access uncertainties due to particulate depolarization ratios and particulate backscatter at 180 degree.

This study will introduce the theoretical basis and algorithms of CALIPSO Bbp product and its advantage over passive remote sensing. It will also discuss the shortcoming and limitation of the current lidar measurements and the improvements that can be made in next generation of space lidars.

8526-19, Session 5

High energy solid-state 2-micron laser transmitter development for wind and CO₂ measurements

Upendra N. Singh, Jirong Yu, Mulugeta Petros, Michael J. Kavaya, Grady J. Koch, NASA Langley Research Ctr. (United States); Yingxin Bai, Science Systems and Applications, Inc. (United States)

Sustained research efforts at NASA Langley Research Center during last fifteen years have resulted in a significant advancement in 2-micron diode-pumped, solid-state laser transmitter for wind and carbon dioxide measurement from ground, air and spaceborne platform. Solid-state 2-micron laser is a key subsystem for a coherent Doppler lidar that measures the horizontal and vertical wind velocities with high precision and resolution. The same laser, after a few modifications, can also be used in a Differential Absorption Lidar system for measuring atmospheric CO₂ concentration profiles. Researchers at NASA Langley Research Center have developed a compact, flight capable, high energy, injection seeded, 2-micron laser transmitter for ground and airborne wind and carbon dioxide measurements. It is capable of producing 250 mJ at 10 Hz by an oscillator and one amplifier. This compact laser transmitter was integrated into a mobile trailer based coherent Doppler wind and CO₂ DIAL system and was deployed during field measurement campaigns. This paper will give an overview of 2-micron solid-state laser technology development and discuss results from recent ground-based field measurements.

8526-20, Session 5

i-LOVE: ISS-JEM lidar for observation of vegetation environment

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It is very important to watch the spatial distribution of vegetation biomass and changes in biomass over time, representing invaluable information to improve present assessments and future projections of the terrestrial carbon cycle. A space lidar is well known as a powerful remote sensing technology for measuring the canopy height accurately. This paper describe the ISS(International Space Station)-JEM(Japanese Experimental Module)-EF(Expansed Facility) borne vegetation lidar using a two dimensional array detector in order to deduce measurement error of tree height due to ground slopes.

8526-21, Session 5

Simulation and visualization of echo signals from forest for iLOVE

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The paper describes the methodology adopted for developing an echo signal simulator from forest for iLOVE (iss-jem Lidar Observation of Vegetation Environment). The goals are developing the echo signal simulation model and visualizing the generation process of the echo
signal. The simulator is conceived having four components: 1) Terrain and features component, 2) Sensor configuration component, 3) Echo signal generation component and 4) Visualization component. An echo signal was generated by a ray tracing method with footprint size, illuminating angle, pulse width, structure of terrain and features, and reflectance of terrain and features at specific wavelengths. Terrain and features data were defined by full polygon in a 3D space. A laser beam had a number of sub laser beams and each sub laser beams had specific intensity based on TEM00. Furthermore, time-series intensity change of sub laser beams was based on a Gaussian distribution. In the echo signal generation process, firstly, intersections between sub laser beams and target objects were calculated. Secondly, echo signal of sub laser beams and target objects were calculated by intersections, pulse width and specific reflectance of target objects. Finally, an echo signal suitable for footprint size was calculated by a synthesis of echo signal of sub laser beams. Furthermore, intersections were drawn on surface of target objects in the 3D space. The results indicate that the simulator was useful for understanding relationship between the echo signal and the structure of target objects, and for developing algorithm for forest applications.

8526-22, Session 5
Measuring forest canopy height usingICESat/GLAS data for applying to Japanese spaceborne lidar mission
Masato Hayashi, Nobuko Saigusa, Hiroyuki Oguma, Yoshiki Yamagata, National Institute for Environmental Studies (Japan); Gen Takao, Forestry and Forest Products Research Institute (Japan); Haruo Sawada, The Univ. of Tokyo (Japan); Kohel Mizutani, National Institute of Information and Communications Technology (Japan); Nobuo Sugimoto, National Institute for Environmental Studies (Japan); Kazuhiro Asai, Tohoku Institute of Technology (Japan)
Spaceborne LiDAR onboard the International Space Station (ISS) is now planned in Japan. The name is iss-jem Lidar for Observation of Vegetation Environment (i-LOVE) and its aim is to measure forest structure globally. In order to acquire the knowledge used for its design, we analyzed ICESat/GLAS data. The method of measuring canopy height using GLAS data was developed for the forest in Hokkaido, and its accuracy and problem were clarified. Utilizing these knowledge, the characteristics of spaceborne LiDAR suitable for forest observation were investigated, e.g. transmit frequency and direction of laser, size and division of footprint, and assumed measuring accuracy.

8526-23, Session 6
Lidar remote sensing of atmospheric aerosol and cloudiness: Monte Carlo modeling
Boris A. Kargin, Evgeniya Kablukova, Arseny B. Kargin, Institute of Computational Mathematics and Mathematical Geophysics (Russian Federation)
At the present time LIDAR systems are widely implemented in research of atmospheric aerosol microphysical properties transformations in time and space and of the dynamics of development and proliferation of cloud formations. Undoubtedly the advantages of laser detectors are high sensitivity in finding even small aerosol contaminants in the atmosphere, long range and great efficiency. To interpret the data of LIDAR experiments the so-called equation of laser sensing, obtained in the single scattering approximation, is used. However the propagation of radiation in dense scattering media (dense hazes, mist, clouds) is accompanied by multiple scattering which is more sensitive to the change of microstructure of the sensed medium in comparison with single scattering and therefore it is preferable to take multiple scattering into account when solving the inverse problem. In real atmosphere conditions the microphysical properties of the scattering medium experience randomly-inhomogeneous variations in time and space. Therefore direct and inverse problems of laser sensing should be considered in the stochastic approach, when the initial optical parameters in the transfer equation, which describes multiple scattering, are defined in the form of random functions of space and time. Solving the transfer equation with random parameters is best carried out by the Monte Carlo method. Obviously, statement of direct and inverse problems of laser sensing theory in these conditions should be based upon the analysis of functional and correlation connections which define informativeness and interdependence of the estimated and measured parameters in a given experiment. In this paper a brief description of a new effective algorithm of the Monte Carlo method is presented, as well as a corresponding modeling program for modeling a non-stationary laser echo-signal. The results of a big series of numerical experiments are also presented. These results establish numerically the correlation connections between the time base of the echo-signal and the random space-time variation of the vertical profile of atmosphere aerosol and particles of the lower tier of liquid droplet clouds.

8526-25, Session 6
Interaction between the low altitude atmosphere and clouds by high-precision polarization lidar
Tatsuo Shinya, Chiba Univ. (Japan); Kazuo Noguchi, Chiba Institute of Technology (Japan); Tetsuo Fukuchi, Central Research Institute of Electric Power Industry (Japan)
High precision polarization lidar has been developed for the prediction of local weather disaster; heavy rain and lightning strike. This lidar has the high extinction ratio of polarization of more than 30dB to estimate the small rotation angle of polarization plane of the echo, which is caused by Faraday effect. The Faraday effect is oriented on the propagating beam and returning echoes by the lighting discharge in the ionized atmosphere. The rotation angle is verified so small that the specially designed optical circulator was installed into the lidar optics to accomplish the high precision polarization measurement. The inline optics is installed to observe the atmosphere in near range. Now, the observation continues through a year. In this study, the interaction between the low altitude atmosphere and cloud is observed especially in bad weather conditions. The low altitude atmosphere leads rainfalls and lightning strikes, and the monitoring of its behavior is important for the prediction. The practical data will be shown by discussing their accordance with fundamental weather parameters such as temperature, humidity, and wind information. The observation is conducted with low elevation angle. The obtained data indicates the unique cloud activities. The authors analyzes the cloud behaviors in the view point of the weather predictions.

8526-26, Session 6
Low altitude fog-haze measurements by Raman-Rayleigh-Mie lidar in Nanjing
Nianwen Cao, Nanjing Univ. of Information Science & Technology (China)
This paper presents the Fog-Haze measurements by Raman-Rayleigh-Mie Lidar in North suburb of Nanjing, the measurement results are analyzed and compared with the weather forecast. Continuous measurements are carried out on 2009/12/2, it is clear day from 01:00 to 08:00 in the morning, and Fog-Haze is measured from at 10:00 in the morning to 19:00 in the evening. The Fog-Haze measurement results coincide with the weather forecast that very day. The Fog-Haze Lidar measurement results on 2009/12/2 are analyzed and compared with the boundary aerosol measurement results on 2010/01/10, the differential characters of range-corrected-signals between Fog-Haze and boundary aerosol are discussed. It is shown that Fog-Haze usually occurs at about 300–400m height and boundary aerosol usually occurs at 1000m height in Nanjing.

8526-27, Session 6
Improvement of NIES lidar network observations by adding Raman scatter measurement function
Tomoaki Nishizawa, Nobuo Sugimoto, Ichiro Matsui, Atsushi
Shimizu, National Institute for Environmental Studies (Japan)

We have conducted ground-based lidar network observations in wide areas of the East Asia using two-wavelength (532 and 1064nm) backscatter and one-wavelength (532nm) depolarization Mie-scatter lidars for more than ten years. To realize more advanced aerosol classification and retrieval, we improved the Mie-scatter lidars at several main sites by adding a N2 Raman scatter measurement channel (607nm). The Mie-Raman lidar system provides 1(±2)+10+1 data in nighttime: extinction coefficient (c) at 532nm, backscatter coefficient (σ) at 532 and 1064 nm, and depolarization ratio (r) at 532nm. We also developed an algorithm to estimate vertical profiles of 532nm extinction coefficients of black carbon, dust, sea-salt, and air-pollution aerosols consisting of mixture of sulfate, nitrate, and organic carbon substances using the 1(±2)+10+16 data. With this method, we assume an external mixture of the aerosol components and UNSCAT type aerosol type indices, aerosol size shapes. The measured lidar data are automatically transferred to the NIES data server. We developed an algorithm to estimate particle optical properties (1(±2)+100 data), planetary boundary layer (PBL) height, and scene classification identifiers representing molecule-rich, aerosol-rich, or cloud-rich layer automatically and provide their quick-looks in semi-real-time on the website (http://www-lidar.nies.go.jp/shingakujutsu/Raman/). We present the developed Mie-Raman lidar and the aerosol classification algorithm and demonstrate their performances.

8526-28, Session 6
Lidar measurements of dust aerosols and dusty cloud over Northwest China
Zhongwei Huang, Jianping Huang, Jianrong Bi, Lanzhou Univ. (China)

Dust aerosols have been shown that they could have a significant impact on the Earth’s radiation budget and regional and globe climate. They not only may mix with other pollutants in the atmosphere then change their characteristics, but also act as ice nuclei then change ice cloud formation and optical properties. To better understand the characterizations of dust aerosols near dust source, lidar measurements of aerosols and cloud were conducted at five sites over Northwest China, which is one of the largest dust sources in the world, including Taklimakan desert and Gobi desert. Dust optical properties, such as depolarization ratio, backscatter ratio, optical depth and size distribution, were discussed in detail combing lidar and other instruments observations. Furthermore, dusty cloud that the mixture of dust and clouds was selected and analyzed based on the observation datasets for studying dust-cloud interaction.

8526-29, Session 6
Observation and analysis of urban boundary layer characteristics with Raman-Mie lidar
Qing Yan, Dengxin Hua, Yufeng Wang, Shichun Li, Jiandong Mao, Xi’an Univ. of Technology (China); Takao Kobayashi, Univ. of Fukui (Japan)

Long-term observations of atmosphere aerosol optical properties over Xi’an area have been carried out by a Raman-Mie lidar and a micro-pulsed 3D Scanning Mie lidar, which were built at Xi’an University of Technology with the laser wavelength of 355nm and 532nm, respectively. The Raman-Mie lidar is used for observation of the atmospheric temperature, humidity and aerosol profiles simultaneously. In order to deeply discuss the temporal-spatial evolution of the mixed-layer within the urban boundary layer, the method of calculating the absolute minimum of first derivatives and second derivative of the range-squared-corrected signal (RSCS) of lidar was used to retrieve the mixed-layer depth (MLD). By using a continuous observations of 24-hour (TH display), the MLD in temporal-spatial evolution are clearly revealed. Also, the results of continuous observations from July 2006 to June 2011 have been analyzed for revealing the diurnal cycle and the annual cycle of the MLD. By analyzing the average MLD, it is obviously shown that the MLD of annual cycle is higher in summer than in winter over Xi’an area. Otherwise, we also studied the relationship of atmospheric boundary layer height, water vapor and temperature and obtained their dependence characteristics and a general disciplinarian. The achievement is of great importance for studying the proliferation of urban pollution and obtaining a complete meteorological status of the urban atmosphere.

8526-30, Session 6
Determination of atmospheric boundary layer height using combined scanning Mie lidar and vertical Raman lidar measurements
Fei Gao, Xi’an Univ. of Technology (China) and Univ. of Nova Gorica (Slovenia); Samo Stanic, Univ. of Nova Gorica (Slovenia); Dengxin Hua, Xi’an Univ. of Technology (China); Klemen Bergant, Univ. of Nova Gorica (Slovenia)

Temporal and spatial variation of atmospheric boundary layer (ABL) height between the Ottica observatory (45.30°N, 13.91°E, elevation 945m a.s.l.) and the Adriatic coast was explored using combined scanning Mie lidar and vertical Raman lidar measurements. Both systems were oriented towards southwest with a fixed azimuth angle of 235.1°. In the case of the Mie scattering lidar, a series of 2-dimensional spatial scans was performed to obtain atmospheric conditions along the line of sight. Spatially averaged values of atmospheric optical depth and atmospheric extinction in the study region were retrieved based on the two- and multi-angle method and under the assumption of horizontal atmospheric homogeneity. In the case of the Raman scattering lidar, a series of 2-dimensional spatial scans was performed to obtain atmospheric conditions along the line of sight. Spatially averaged values of atmospheric optical depth and atmospheric extinction in the study region were retrieved based on the two- and multi-angle method and under the assumption of horizontal atmospheric homogeneity. In the case of the Raman scattering lidar, a series of 2-dimensional spatial scans was performed to obtain atmospheric conditions along the line of sight. Spatially averaged values of atmospheric optical depth and atmospheric extinction in the study region were retrieved based on the two- and multi-angle method and under the assumption of horizontal atmospheric homogeneity.
and internal layer has strong daytime variability. High values of relative humidity and marine air masses produces dense atmospheric haze and responsible for high values of PBL AOT in the morning. While heating the atmosphere AOT monotonically decreases reaching its minimal values at the sunset.

8526-32, Session PSWed

3-year-program to improve critical 1-micron Qsw laser technology for earth observation

Daisuke Sakaizawa, Yohei Satoh, Shiro Yamakawa, Japan Aerospace Exploration Agency (Japan); Satoshi Wada, Takayo Ogawa, RIKEN (Japan); Shoken Ishii, Kohei Mizutani, Motoaki Yasui, National Institute of Information and Communications Technology (Japan)

Laser remote sensing technologies are valuable for a variety of scientific requirements. These measurement techniques are involved in several earth science areas, including atmospheric chemistry, aerosols and clouds, wind speed and directions, prediction of pollution, oceanic mixed layer depth, vegetation canopy height (biomass), ice sheet, surface topography, and others. Much of these measurements have been performed from the ground to aircraft over the past decades. To improve knowledge of these science areas with transport models (e.g. AGCM), further advances of vertical profile are required.

JAXA collaborated with NICT and RIKEN started a new cross-sectional models (e.g. AGCM), further advances of vertical profile are required. To improve knowledge of these science areas with transport

8526-33, Session PSWed

Study on all-fiber Mach-Zehnder interferometer as frequency discriminator for Doppler wind lidar

Li Wang, Xi’an Univ. of Technology (China); Wei Hao, Xi’an Institute of Optics and Precision Mechanics (China); Yi Zhou, Linqiu Tan, Yufeng Wang, Shichun Li, Jing Le, Dengxin Hua, Xi’an Univ. of Technology (China)

The principle of all-fiber Mach-Zehnder interferometer (AFMZ) as frequency discriminator for wind speed measurement by direct detection Doppler lidar is proposed. All-fiber Mach-Zehnder interferometer has feature of a high transmission, wide field of view, a large luminous flux, high stability and small size. The wind detection principle and retrieve method of AFMZ as frequency discriminator of Doppler wind lidar are studied. The parameters of frequency discriminator are designed and optimized by numerical simulation. For a lidar operating at 532nm, the optical path difference of AFMZ is optimized to be 3.25cm. By considered the different coupling mode, the coupling efficiency of telescope with receiving fiber is optimized to be 3.25cm. By considered the different coupling mode, the coupling efficiency of telescope with receiving fiber is constructed and the wind speed is retrieved from given parameters. The research will provide available technology and method for development of a new wind lidar based on space or satellite platform.

8526-34, Session PSWed

Remote sensing of hydrogen gas concentration distribution by Raman lidar

Ippei Asahi, Sachiyu Sugimoto, Hideki Ninomiya, Shikoku Research Institute Inc. (Japan); Tetsuo Fukuchi, Central Research Institute of Electric Power Industry (Japan); Tatsuo Shiina, Chiba Univ. (Japan)

Hydrogen is expected to become an energy source in the next generation. Although hydrogen gas is a combustible gas with a large explosion concentration range, leakage is presently monitored by contact type gas sensors. The technology for locating a leak and remote sensing of gas concentration distribution is required in case of hydrogen gas leaks. In this research, technology of hydrogen gas concentration distribution using a Raman lidar was developed. The lidar system consisted of a pulsed Nd:YAG laser of wavelength 355 nm and a Galilean telescope of aperture 170 mm. The system could detect hydrogen gas by vibrational Raman scattering. In this method, hydrogen gas concentration could be measured based on the ratio of the Raman scattering signals from hydrogen gas and from atmospheric nitrogen, which were simultaneously measured. In this manner, the geometrical form factor of the biaxial lidar and the instrumental function were canceled. Hydrogen gas concentration of 0.6-100% could be measured at a distance 13m using this system.

8526-35, Session PSWed

The characteristics of solid etalon Doppler discriminator and transmitter in designing Doppler lidar

Dukhyeon Kim, Hanbat National Univ. (Korea, Republic of); Hae-Du Cheong, Korea Atomic Energy Research Institute (Korea, Republic of)

Doppler lidar system and RADAR wind profiler have been used for long time in meteorological measurement field, military and airport safety applications. But these systems are bulky, expensive and complex to use in airplane and other mobile system. Here we have suggested new type of Doppler transmitter and discriminator to decrease its complexity, size and price. We have calculated transmitting and receiving characteristics of unseeded Nd:YAG laser. In our calculation we have used 4 HGz, 30 free spectral range etalon and effective finesse. And we find that the Solid etalon Doppler discriminator can be used as a Doppler discriminator when the unseeded pulsed laser is transmitted through the same etalon. And more this system is 2.8 times more sensitive than traditional iodine based Doppler discriminator when we use two discriminators with different incident angles. And because spectral jittering and other spectral effect is not effective, and mechanical angle can be precisely and stably controlled by simple method, we can expect inexpensive, small size, and simple Doppler lidar system. To check this possibilities, we have measured the speed of rotating wheel by using unseeded laser and solid etalon Doppler discriminator. And find that this configuration can be successfully used in Doppler lidar system.

8526-36, Session PSWed

Performance evaluation of coherent 2-µm differential absorption and wind lidar for wind measurement

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A coherent 2-µm differential absorption and wind lidar (Co2DiaWiL) has been built with a high power Q-switched Tm,Hm:YLF laser to measure CO2 concentration and radial wind velocity. Our experiment was conducted to test the ability of the Co2DiaWiL to make wind measurement in the atmospheric boundary layer and lower free troposphere. The bias in the velocity measurement was estimated as
-0.0069 m/s using measurements from a stationary hard target. The magnitude of the random error of radial velocity measurements was determined from data in the vertical pointing mode and the Co2DaWiL achieved a velocity precision of 0.12 m/s.

The radial velocity measurements to ranges up to 20-25 km by the horizontally fixed beam mode for average times of 1 min have been demonstrated with the high laser output power.

8526-37, Session PSWed

Evaluation of water vapor Raman lidar signals from clouds
Tetsuo Fukuchi, Takashi Fujii, Central Research Institute of Electric Power Industry (Japan)

Raman lidars are commonly used for measurement of water vapor profiles in the lower atmosphere. However, the treatment of the Raman lidar signals from clouds is not well established. Raman lidar observations were conducted at the coastal area of Yokosuka, Japan, using a laser wavelength of 280 nm. Raman scattering signals from water vapor and atmospheric nitrogen were simultaneously measured at the zenith direction. When clouds existed, the water vapor Raman scattering signals were observed to increase from almost zero at the cloud base to a maximum at a penetration distance of about 50 m. The nitrogen Raman scattering signals showed a monotous decrease beyond the cloud base, indicating that the water particle content was almost constant. A simplified model taking multiple scattering into account was devised to explain the behavior of the water vapor Raman scattering signal. The model results in a difference of two exponential functions, one which represents the extinction of laser light inside the cloud, and another which represents the effect of multiple scattering. The model could sufficiently explain the variation of the water vapor Raman scattering signal with respect to the penetration distance into the cloud.

8526-38, Session PSWed

Meteorological observation with Doppler and Raman lidars and comparison with numerical weather simulations
Hidetoshi Tamura, Naoto Kihara, Takashi Fujii, Tetsuo Fukuchi, Koji Wada, Hiromaru Hirakuchi, Central Research Institute of Electric Power Industry (Japan)

Meteorological observation data such as temperature, humidity, wind speed and wind direction are important for validating and improving numerical weather simulation models. Lidar is an effective method for acquiring such data with high range resolution and short time intervals. In this study, we carried out a field observation with coherent Doppler Ladar (DL) and Raman Lidar (RL) systems at the coastal area of Yokosuka, Japan, and compared the observed data with the results of numerical weather simulations. We obtained the vertical profiles of horizontal wind speeds and wind directions by DL with 65 m vertical range resolution, and the vertical profiles of the water vapor mixing ratio by RL with 20 m vertical range resolution at the lower atmospheric boundary layer (200-600 m height from ground level). These data were acquired at time intervals of 10 minutes. We found an interesting phenomenon from observed data indicating that, under weak wind conditions, water vapor in the atmosphere significantly increased just after a definite change in wind direction from land breeze to sea breeze. A similar phenomenon was also predicted by the numerical weather simulation with the same meteorological and terrestrial conditions. We analyzed the numerical results and found that the change in water vapor mentioned above is mainly caused by the difference between the evaporation from land and sea surfaces, which were located upwind of the land and sea breezes, respectively. Water vapor is by far the most important greenhouse gas in the atmosphere. Water vapor and clouds play an important role in weather and climate on local to global scales. For better understanding of water vapor and clouds processes in the Qinghai-Tibetan Plateau, this work is to design and establish a Raman-Mie-Rayleigh lidar capable of continuous vertical profiling of tropospheric water vapor, aerosol and cloud with high temporal and vertical resolution in day and night. The lidar transmitter is a high power Nd:YAG laser operating at three wavelengths of 355nm, 532nm and 1064nm. Four receiver telescopes compose a telescope-array with total aperture equal to a single large telescope. The lidar polychromator based on the high-resolution grating is used to detect the backscatter Raman signals from water vapor, nitrogen and oxygen to calculate the atmospheric water vapor concentration, which is stimulated by the 355nm laser emission. Aerosol and cloud profiling is achieved by the Mie-Rayleigh lidar methodology operating at the wavelength of 532nm and 1064nm. Depolarization of laser light backscattered by non-spherical particle in the atmosphere is also derived. The provided observations will improve the database available in the Qinghai-Tibetan Plateau for direct meteorological applications and could increase the accuracy of numerical weather prediction.

8526-39, Session PSWed

Multi-wavelength lidar for water vapor and cloud properties measurements
Shengguang Qin, Songhua Wu, Ocean Univ. of China (China)

Observation of aerosol parameters at Saga using GOSAT product validation lidar
Shoichiro Takubo, Hiroshi Okumura, Takeru Kawasaki, Indra N. Abdullah, Saga Univ. (Japan); Osamu Uchino, Isamu Morino, Tatsuya Yokota, National Institute for Environmental Studies (Japan); Tomohiro Nagai, Tetsu Sakai, Takashi Maki, Meteorological Research Institute (Japan); Kohei Arai, Saga Univ. (Japan)

Global warming has become a very serious issue for human beings. Scientists have suggested that, at the rate the Earth's temperature is rising, an extreme form of global climate change could occur in a few centuries. In 1997, the Kyoto Protocol was adopted at the Third Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3), making it mandatory for developed nations to reduce carbon dioxide emissions by six to eight per cent of their total emissions in 1990, and to meet this goal sometime between 2008 and 2012. Furthermore, the Global Climate Observation System (GCOS) has been proposed by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) in order to strengthen observations of land, ocean, and space conducted by each country. So far, the number of ground-based carbon dioxide observation points has been limited, and they have been distributed unequally throughout the world. Greenhouse gas Observation Satellite (GOSAT) enables the precise monitoring of the density of carbon dioxide by combining global observation data sent from space with data obtained on land, and with simulation models. In addition, observation of methane, another greenhouse gas, has been considered. For validation of GOSAT data products, we have continued ground-base observation with Fourier Transform Spectrometer (FTS), aerosol lidar and ozone-DIAL lidar at Saga University, JAPAN since March, 2011. In these equipment, aerosol lidar system is a mono-static and has a Nd:YAG laser for its light source. The system has 4 different wavelength channels, parallel and perpendicular polarized channel at 532[nm], 1064[nm] and 607[nm] for Raman shift caused by nitrogen molecules. For analysis of this aerosol lidar data, not only acquired lidar data but also meteorological data are required. We automatically obtain the following meteorological or image data for aerosol data analysis:
1) AMeDAS ground-level meteorological data from Saga city AMeDAS station every 10 minutes;
2) AMeDAS Rawinsonde high altitude meteorological data from Fukuoka city AMeDAS station twice (00Z and 12Z) a day;
3) images taken by a Skyview camera established on the roof of the
building adjacent to the aerosol lidar are acquired every 5 minutes in
daytime;
4) meteorological satellite (MTSAT) IR image data are acquired every
hour.
AMeDAS ground-level meteorological data, AMeDAS RawinSonde
high altitude meteorological data are used for estimation of extinction
coefficient caused by Rayleigh scattering. The US standard
atmosphere model is used for estimation of extinction coefficient
above the stratosphere.
Skyview camera images and meteorological satellite IR image data are
required to confirm clouds above lidar.
In this study, observation results obtained from aerosol lidar are
reported. Seasonal or annual tendency of scattering ratio, wavelength
dependency, depolarization and lidar ratio is also shown.

8526-43, Session PSWed

Possible atmospheric and oceanic
observations with ISS-JEM lidar
observation of vegetation environment
(i-LOVE)
Tomoei Nishizawa, Nobuo Sugimoto, National Institute
for Environmental Studies (Japan); Kohei Mizutani, Shoken
Ishii, National Institute of Information and Communications
Technology (Japan); Kazuhiro Asai, Tohoku Institute of
Technology (Japan)
We present possibilities of atmospheric and oceanic observations
by a two wavelength (1064 and 532nm) Mie-scattering lidar from
space with ISS-JEM Lidar Observation of Vegetation Environment
(i-LOVE) that is being proposed to the Japan Aerospace Exploration
Agency (JAXA). The performance of the lidar currently considered is
not as good as CALIOP as an atmospheric lidar, however, the data
will be useful for observing distributions of aerosols and clouds. The
non-sun-synchronous orbit of ISS will allow observation of diurnal
variations of clouds and aerosols. The lidar signals from sea surface
will be useful to derive surface wind speed. The multi-element (or
imaging) lidar capability of the lidar may provide additional information
in the analysis. The backscattering profiles under the sea surface with
the 532-nm cross-polarization channel can be used for estimating
chlorophyll concentration with the method developed by Y. Hu.
8527-1, Session 1

The Cross-track Infrared Sounder (CrIS) on Suomi NPP: expected radiometric and spectral performance and calibration/validation results: part I (Invited Paper)

Henry E. Revercomb, David C. Tobin, Robert O. Knuteson, Daniel H. DeSoer, Joseph K. Taylor, Graeme Martin, Raymond K. Garcia, Lori Borg, Univ. of Wisconsin-Madison (United States)

The new CrIS sounder on Suomi NPP (launched on 28 October 2011) measures high spectral resolution infrared radiances (resolving power >1000) covering three broad bands of the spectrum between 3.8 and 15.4 microns. CrIS, as the operational follow-on to the Atmospheric Infrared Sounder (AIRS) on the NASA Aqua platform, provides temperature and water vapor soundings from the 1330 afternoon orbit, while 930 morning soundings are provided by the Infrared Atmospheric Sounder Interferometer (IASI) on the European Metop A. For climate, the CrIS and IASI instruments on what is now called the Joint Polar Satellite System will extend the AIRS record of highly accurate spectrally resolved radiances (<0.2-0.5 °C 3-sigma) well into the 2020s.

This presentation will briefly review the design of the CrIS built by Exelis (formerly ITT) and ABB/Bornem, present recent analyses characterizing the spectral and radiometric performance of CrIS, and suggest possible upgrades to future US IR sounders.

8527-2, Session 1

Performance status of the Atmospheric Infrared Sounder ten years after launch

Thomas S. Pagano, Hartmut H. Aumann, Denis A. Elliott, Steven E. Broberg, Jet Propulsion Lab. (United States)

The Atmospheric Infrared Sounder (AIRS) is a hyperspectral infrared instrument on the EOS Aqua Spacecraft, launched on May 4, 2002. AIRS has 2378 infrared channels ranging from 3.7 µm to 15.4 µm and a 13.5 km footprint at nadir. The AIRS is a “facility” instrument developed by NASA as an experimental demonstration of advanced technology for remote sensing and the benefits of high resolution infrared spectra to science investigations. AIRS, in conjunction with the Advanced Microwave Sounding Unit (AMSU), produces temperature profiles with 1K/km accuracy on a global scale, as well as water vapor profiles and trace gas amounts for CO2, O3, CO2, O3 and CH4. AIRS data are used for weather forecasting, climate process studies and validating climate models.

AIRS radiances have been stable during the last 10 years to better than 10 mK/year. A major player in the instrument stability has been a temperature controlled optical bench and an SI traceable on-board blackbody with an emissivity of better than 0.999. This paper discusses small changes in detector properties and spectral frequencies which have occurred in the past ten years, and how the changes are detected and mitigated. For example, over 150 detectors were identified has having excessive noise due to long term radiation exposure and of these 90 were recovered by switching to a new gain state. Instrument telemetry shows little degradation with time and we expect the AIRS to operate for many years, limited only by the life of the spacecraft that is currently projected to run out of fuel in 2022. The AIRS instrument is well suited to climate observations due to the high sensitivity and resolution, wide dynamic range, exceptional stability, SI traceability of the on-board blackbody, and excellent documentation available in the open literature.

8527-3, Session 1

Temperature and moisture sounding from Suomi NPP ATMS/CRIS sounder suite

Xu Liu, NASA Langley Research Ctr. (United States); Susan H. Kizer, Science Systems and Applications, Inc. (United States); Daniel K. Zhou, Allen M. Larar, NASA Langley Research Ctr. (United States); Christopher D. Barnet, Murty G. Divakarla, Guang Guo, X. Xiong, M. Wilson, National Oceanic and Atmospheric Administration (United States); D. Gui, Northrop Grumman Aerospace Systems (United States)

The Suomi NPP Cross-track Infrared Microwave Sounding Suite (CrIMSS) consists of the infrared (IR) Cross-track Infrared Sounder (CrIS) and the microwave (MW) Advanced Technology Microwave Sounder (ATMS). We have successfully tuned and applied the ported CrIMSS operational code to the CrIMSS focus day data. The results will be presented at the conference.

8527-4, Session 1

Retrieval of carbon dioxide and ozone from thermal infrared spectra observed by GOSAT TANSO-FTS sensor over urban area

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Synergetic usage of multi-band spectral data observed by the main sensor, TANSO-FTS, of the greenhouse gas observing satellite (GOSAT) is expected to improve the retrieval performance for CO2 concentration in the lower atmosphere compared to the retrieval using single band data. We have evaluated the effectiveness of the additional usage of 10µm absorption (laser) band to 15µm band based on simulation studies. The results show that the addition of 10µm band data increases the sensitivity to the CO2 variations by about 10-20 % in the atmosphere below 2 km under the condition that the surface temperature is same as that of the surface level atmosphere. Generally, the sensitivity strongly depends on the thermal contrast between the atmosphere and the surface, i.e., if the surface temperature is higher enough compared to the atmospheric temperature, the sensitivity increases like the occultation measurement. Simulations showed that the sensitivity drastically increases when the surface temperature is higher by about 10 K than the surface level atmospheric temperature implying the possibility to detect the columnar concentrations of CO2 only from the thermal infrared spectra. These situations expected to occur during the daytime, particularly in the summer time over the urban area where the surface is mostly covered with asphalt or concrete. We analyzed the data obtained during the GOSAT specific observation mode targeting at Tokyo city and compared the results with concentration profiles measured by CO2 sonde and surface concentrations simulated with a meso-scale transport model, AIST-MM.

8527-5, Session 1

Atmospheric sounding information obtainable from present-day advanced infrared systems

Allen M. Larar, Daniel K. Zhou, Xu Liu, NASA Langley Research
8527-6, Session 1

**Hyerspectral measurements of greenhouse gases**

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Measurements of Green House Gases (GHGs) can be inferred from satellite and ground based hyperspectral radiance measurements. Satellite measurements are primarily sensitive to the free troposphere and stratosphere while surface based observations are primarily sensitive to the planetary boundary layer below 3 km. Techniques have been developed for retrieving GHG profiles from satellite measurements alone, surface based measurements alone, and from the combination of surface based and satellite measurements. Here the algorithm is defined and results obtained during several field programs, including the NGA Cooperative Atmospheric Measurement program (CAMP), are presented.

8527-7, Session 1

**Methane retrieval from ground-based AERI Anmyeondo, Korea and its validation**

Tae-Young Goo, Mi-Lim Ou, National Institute of Meteorological Research (Korea, Republic of); Zen H. Mariani, Kimberly Strong, Univ. of Toronto (Canada); Mathias Palm, Univ. Bremen (Germany)

The National Institute of Meteorological Research (NIMR) has operated the ground-based Atmospheric Emitted Radiance Interferometer (AERI) at Anmyeondo, Korea (36.539 N, 126.330 E) since June 2010. The AERI observes downwelling infrared emission from 550 to 3000 cm⁻¹ with a spectral resolution of 1 cm⁻¹. In order to retrieve methane from AERI spectra, a modified version of the SFIT2 algorithm was employed in collaboration with the University of Toronto and the University of Bremen. The Methane retrieval was computed using measured AERI radiance on a clear-sky day only from June 2010 to December 2011. The profiles of atmospheric temperature and pressure (± 50 hPa) from a numerical weather prediction (NWP) model (Unified Model of KMA (Korea Meteorological Administration)) were merged with those (± 50 hPa) from the 1976 US Standard Atmosphere. The AERI methane profile was estimated using a retrieved total column of methane which has DOFs≈1.0.

Volume mixing ratios of methane retrieved in the lowermost layer (0.031–1 km) were validated using ground-based in-situ measurements (GC7890N-FID) made from a tower at a height of 0.086 km. It was found that the average difference between the AERI and in-situ methane volume mixing ratios was about 200 ppbv. The variability in the AERI methane retrievals is considerably larger than that of in-situ observations. This is under investigation, but may be due to insufficient resolution in the AERI spectra. Despite the large variability, AERI total column retrievals are likely to play an important role in improving the retrieval algorithms of satellite-based hyperspectral remote sensing in the lower troposphere.

8527-8, Session 1

**A combined atmospheric radiative transfer (CART) model and its applications for cirrus clouds simulations**

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A fast atmospheric radiative transfer model called Combined Atmospheric Radiative Transfer model (CART) has been developed to rapidly calculate atmospheric transmittance and background radiance in the wavelength range from 1 to 25000 cm⁻¹ with spectral resolution of 1 cm⁻¹. The CART can be used to fast compute spectral transmittance, thermal radiance, scattering radiance, direct solar irradiance, by atmospheric molecules, aerosols and clouds. Cirrus clouds are assumed with a layer of ice crystal in the atmosphere. The single-scattering properties (i.e extinction efficiency, single-scattering albedo, and scattering phase function) of cirrus clouds are parameterized as the function of effective diameter of cirrus clouds. A fast multiple-scattering algorithm based on re-arranged DISORT is presented for multiple-scattering radiance calculation in a broad band.

The spectral radiative properties of cirrus clouds at various effective diameters, optical thicknesses, and altitudes from visible to far-infrared wavelength region are simulated using the CART. The analyses show that the properties of cirrus clouds might be retrieved from the satellite-based spectral characteristics of cirrus clouds based on these simulations.

8527-9, Session 2

**Feature extraction with the AD-LIsomap method for classification of hyperspectral imagery**

Wewei Sun, Chun Liu, Beiqi Shi, Weiyoue Li, Tongji Univ. (China)

Due to the problem of “curse of dimensionality”, feature extraction is always an essential process before classification of Hyperspectral imagery (HSI). In recent years, considering the nonlinear features of HSI data, Isomap have been popular in the feature extraction. Isomap could discover nonlinear manifold structures of HSI data for classification. However, the total complexity of Isomap reaches up to O(N³) with the pixel number N. Silva then proposed landmark-Isomap (LIsomap) to reduce the complexity, however, the speed improvement takes the cost of degrading the classification accuracies (CAs). Meanwhile, further strategies by Bachmann aiming to ameliorating LIsomap could not guarantee the accurate CAs. Therefore, in this paper, we propose an advanced-LIsomap (AD-LIsomap) to reduce the complexity of Isomap and also improve the CAs. AD-LIsomap introduces vector quantization to improve the landmark selection of LIsomap for improving CAs. Meanwhile, the new method promotes the computational speed through three schemes, random projection, the fast approximate neighbors graph construction and the fast low-rank approximate SVD decomposition. Based on two different HSI data, several groups of experiments has been designed to testify and analyze our method. The result shows that AD-LIsomap greatly promotes the speed of LIsomap, especially for larger numbers of landmarks. The results also show that AD-LIsomap sharply improves CAs in most classes of ground objects compared with LIsomap. In addition, we find that the three speed improvement schemes takes only a little cost of degrading the CAs of AD-LIsomap.

8527-10, Session 2

**Quality evaluation of pansharpened hyperspectral images generated using multispectral images**

Masayuki Matsuoka, Kochi Univ. (Japan); Hiroki Yoshioka, Aichi Prefectural Univ. (Japan)

Hyperspectral remote sensing or imaging spectroscopy can provide a smooth spectral curve of a target by using a set of higher spectral resolution multispectral images
resolution detectors. This spectral information is quite useful for detail analyses of land-surface features such as vegetation or mineral resources. The spatial resolution of the hyperspectral images, however, is generally much lower than that of multispectral images due to the lower energy of incident radiation. Pan sharpening is an image-fusion technique that generates higher spatial resolution multispectral images by combining lower resolution multispectral images with higher spatial resolution panchromatic images. In this study, higher resolution hyperspectral images are generated by pan sharpening of lower hyperspectral images and higher multispectral images. Then, spectral and spatial qualities of pan sharpened images are assessed in terms of the spectral band position of simulated multispectral images generated by hyperspectral data. Airborne hyperspectral data of AVIRIS is used in this study, and pan sharpened using seven methods: additive wavelet intensity, additive wavelet principal component, generalized Laplacian pyramid with spectral distortion minimization, generalized intensity-hue-saturation (GHS) transform, GHS adaptive, Gram-Schmidt spectral sharpening, and block-based synthetic variable ratio. Quantitative evaluations of pan sharpened image are achieved using three frequently used indices, the correlation coefficient, ERGAS, and the Q index. Image qualities of pansharpened hyperspectral data are analyzed with respect to the band position and bandwidth of each data.

8527-11, Session 2
Pan-sharpening based on compressed sensing via truncated 1-norm minimization
Guixia Zhang, Zhihan Jian, East China Normal Univ. (China); Yaxin Peng, Shanghai Univ. (China); Chaomin Shen, East China Normal Univ. (China)
We propose a method for pan-sharpening based on compressed sensing, and implement the method via truncated 1-norm minimization. We consider a high-spectral and high-spatial resolution image as the original image; low-spatial resolution multispectral (LRM) and high-spatial resolution panchromatic (HRP) images are two samples (or degraded versions) of the original image. Thus the pan-sharpening problem is reduced to recover the original image from these two samples. On the other hand, compressed sensing is a technique which makes it possible to recover the original data from fewer samples required by the Shannon-Nyquist sampling theorem under certain conditions. Thus it is natural to use the idea of compressed sensing to tackle this issue. We follow the sparsity assumption of compressed sensing, which could be satisfied since satellite images are sparse under certain dictionary. Thus, for implementing the pan-sharpening problem, we need to 1) construct the dictionary, and 2) minimize the objective function with 1-norm arising from the compressed sensing problem. In our solution, the dictionary is constructed from both LRM and HRP training images; the 1-norm minimization is approximated by a truncated 1-norm minimization. The 1-norm problem is NP hard and an easy algorithm with Bregman iteration is used in the implementation. Experimental results with QuickBird images show the effectiveness of the algorithm.

8527-12, Session 2
A method for enhancing spectral resolution of multispectral satellite imagery
Tao Guo, Toshihiro Kujirai, Takashi Watanabe, Yu Kitano, Yu Zhao, Hitachi, Ltd. (Japan)
Improvement of the spatial, spectral and temporal details of satellite imagery is a driving force behind the commercial success in Earth environment observation industry but remains lots of technical challenges. Among them there is an increasing interest in retrieving the detailed spectral features from multispectral satellite image data despite of the advance of sensor technology. The current methods to enhance the spectral information are mainly focused on image and its attributes, which results in the influences of sensor being little considered and possibly ignored, such as spectral interpolation. Meanwhile the popular spectral unmixing technique suffers from problems of end member extraction. In this research, based on the physical model of sensor response function we present a method to recover the reflective spectrum at the front end of sensor in an iterative way, which can be used to simulate the ideal and continuous spectral curve of objects with little influence from sensor. Accordingly detailed spectral data can be generated from a re-sampling process on the generated spectrum curve. Comparing with the conventional methods, our method has an advantage to recover the reflective spectrum with a faithful preservation of spectral features of objects and no additional information is required except of sensor response function which is normally known. Through experiments, we demonstrated that our method is able to largely increase the cost-performance ratio of satellite multispectral imagery and also reveals great potentials of satellite imagery in various disciplines.

8527-13, Session 2
Spectral unmixing based on non-negative matrix factorization via truncated 1-norm minimization
Chaomin Shen, East China Normal Univ. (China); Yaxin Peng, Shanghai Univ. (China); Guixu Zhang, East China Normal Univ. (China)
Spectral unmixing aims to retrieve the fractional abundances of pure spectral signatures (endmembers) for each pixel in remotely sensed data. One useful tool for linear spectral unmixing is the non-negative matrix factorization (NMF). The matrix A is factorized into a product of an m-by-k matrix W and a k-by-n matrix H, with non-negative entries in all matrices. If each column of A represents the spectral of an observed pixel, it is a linear combination of the columns of W with coefficients from the entries in the same column of H. Hence, the columns of W can be regarded as endmembers, and the column of H is the corresponding abundances if every column of H is normalized. However, the factorization may not be unique due to the non-convexness of the objective function in the issue. To achieve a reasonable solution, the 0-norm constraint is imposed, since given k the total number of class in the scene, it is natural that each pixel only contains a small number of classes. Due to the NP-hard property of 0-norm, in real computation 1-norm is often substituted by 1-norm. In our case it is not applicable as the column vectors in H are normalized. Therefore we adopt the truncated 1-norm, defined as \(||z||_1|| \leq \theta \) with \(\theta > 0\) a tuning parameter controlling the approximation degree, to substitute 0-norm. In the implementation part, difference of convex functions (DC) programming is used to tackle the non-convexness. Experimental unmixing results with QuickBird images show the effectiveness of the algorithm.

8527-14, Session 2
SVM multispectral-texture classification for tropical vegetation mapping
Sébastien Chabrier, Benoît Stoll, Univ. de la Polynésie Française (French Polynesia); Jean-Baptiste Goujon, ESEO (France)
Nowadays, remote sensing is an essential science in French Polynesia because of its extended territory and the remoteness of its 120 islands. There is a strong need to study the vegetation cover and its evolution (biodiversity threat, invasive species, etc.). A growing satellite images database has been acquired throughout, giving access to very high resolution optical images such as Quickbird data. These data allow accessing the vegetation canopy spectral and contextual information. Feature classification methods prove to be an efficient tool to map the complex vegetation found in tropical regions. The main goal of this paper is to propose an optimized SVM multispectral-texture classification method for tropical vegetation mapping. One of the texture computation drawbacks is the window treatment size, which is related to the largest texture element size. In complex tropical vegetation cover, this parameter leads to very small ground truth learning database, inducing a significant degradation of the classifications accuracy. We propose to increase the thumbnail numbers using an under-sampling method, optimizing the size and the number of the thumbnails. The other drawback is the high dimensionality of the problem when dealing with multispectral textures. We thus propose to rank and select the most pertinent textures attributes in order to reduce the
dimensionality without reducing the classification accuracy.

We first introduce the study context, before exposing preliminary studies on tuning the SVM learning method. The adapted method is then accurately exposed and the interesting experimental results as well as a number of applications are presented before to conclude.

8527-15, Session 2

**Emissivity and temperature separation algorithm based on noise separation**

Hang Yang, Lifu Zhang, Institute of Remote Sensing Applications (China)

This paper absorbs the best thinking of Aster_TES and ISSTES algorithms: keeping the shape of emissivity spectra and the assumption of spectra smoothness. Based on them, the authors put forward a new idea to separate the temperature and emissivity. The main steps are follows:

- S1: To estimate the initial temperature: firstly computing the brightness temperatures of each channel, and then selecting the maximum temperature as the initial temperature of the pixel;
- S2: To initialize the temperature step Tstep;
- S3: to compute the emissivity using the formulate 2;
- S4: To smooth the emissivity curve: this step is the most key for this algorithm. The effect of noises-removing decides the improving of temperature accuracy;
- S5: To compute the ground-leaving radiance using filtered emissivity and temperature;
- S6: To compute total mean squares error, and set the terminate term of algorithm. If the error decreases comparing with above step, then setting T=T+Tstep and repeat the step 3; if error doesn’t decrease and Tstep satisfy the terminate term, then algorithm ends; if error doesn’t decrease and Tstep doesn’t satisfy the terminate term, then repeat the step 7.

The results showed that NSTES algorithm not only improves the temperature-image quality but the accuracy of emissivity, compared with Aster_TES and ISSTES algorithms. For the same surface type, the emissivity curve shapes between the retrieved by NSTES algorithm and field-measurement are similar. And NSTES algorithm is characterized by wide application scope and without the prior knowledge of temperature and emissivity, and strong anti-noise capability.

8527-16, Session 2

**A novel statistical method for 3D range data registration based on Lie group framework**

Yaxin Peng, Wei Lin, Shanghai Univ. (China); Chaomin Shen, East China Normal Univ. (China); Shihui Ying, Shanghai Univ. (China)

Registration of range data is to assign correspondences between two point sets and to find the transformation that best maps one data set to the other. It is a key step in many remote sensing areas. In this paper, Lie group parametric representation is combined with the Expectation Maximization (EM) method to provide a unified framework for 3D range data registration. First, by given a transformation, EM algorithm is introduced to find the correspondence between two data sets through correspondence probability which covers the relationship of all points, instead of using exact correspondence such as the classical Iterative Closest Point (ICP) method. With this kind of soft correspondence, we could deal with the presence of the degradations such as outliers and incomplete point sets. Second, by updated correspondence between two data sets and introducing Lie group parametric representation, the transformation is updated by minimizing a quadratic programming. Then, an alternative iterative strategy by the above two steps is used to approximate the desired correspondence and transformation. At last, several comparative experiments between Lie-EM-ICP algorithm and Lie-ICP algorithm are presented. Our algorithm is demonstrated to be more accurate and robust, especially in the presence of incomplete point sets and outliers.

8527-17, Session 3

**Determine the optimum spectral reflectance of juniper and pistachio in arid and semi-arid region**

Hadi Fadaei, Rikie Suzuki, Japan Agency for Marine-Earth Science and Technology (Japan)

Pistacia vera. L (pistachio) and the conifer Juniperus excelsa ssp. polycarpos (Persian juniper). In this study, we estimated the optimum spectral reflectance of juniper forests and natural pistachio stands using remote sensing in Iran. In this research we are able to specified spectral reflectance of multispectral from Advanced Land Observing Satellite (ALOS) that provided by JAXA EORC. These data included PRISM is a panchromatic radiometer with a 2.5 m spatial resolution at nadir, and has one band with a wavelength of 0.52-0.77 μm and AVNIR-2 is a visible and near infrared radiometer for observing land and coastal zones with a 10 m spatial resolution at nadir, and has four multispectral bands. Total ratio vegetation index (TRVI) using 575 maximum filtering algorithm of optimum spectral reflectance of juniper and pistachio have been evaluated. The result of TRVI for Pistacia and juniper were (R2= 0.71 and 0.56).

8527-18, Session 3

**Detection of seagrass beds in Khung Graben Bay, Thailand, using ALOS AVNIR2 image**

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Coastal habitats having high productivity provide numerous ecological services such as foods, protection from strong waves through buffering effect, fixation of CO2 through photosynthesis, fostering biodiversity etc. However, increasing human impacts and climate change decrease or degrade coastal habitats. ASEAN region is developing most rapidly in the world. In the developing region, it is necessary to grasp present spatial distributions of habitats as a baseline data with standardized mapping methods. Remote sensing is one of the most effective methods for mapping. Japan Aerospace Exploration Agency (JAXA) provides non-commercial satellite images with ultra-high spatial resolution optical sensors (10 m), AVNIR2, similar to LANDSAT TM. Using ALOS AVNIR2 images it may be possible to make habitat map in the region. In Thailand, shrimp ponds cause degradation of coastal ecosystem through cutting mangroves and eutrophicated discharge from ponds. We examined capability of remote sensing with ALOS AVNIR2 to map seagrass beds in Khung Kraben Bay, Chanthaburi Province, Thailand, surrounded by shrimp ponds. We analyzed ALOS AVNIR2 taken on 25 January 2008. Ground truth survey was conducted in October 2010 using side scan sonar and scuba diving. The survey revealed that there were broad seagrass beds consisting of Enhalus acoroides. We used a decision tree to detect seagrass beds in the bay with quite turbid seawater coupled with Depth-Invariant Index proposed by Lyzenga (1985) and bottom reflectances. We could succeed to detect seagrass beds. Thus it is concluded that ALOS AVNIR2 is practical to map seagrass beds in this region.

8527-19, Session 3

**Hyperspectral data application for peat swamp forest monitoring in Central Kalimantan, Indonesia**

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Peatland is a large CO2 reservoir which accumulates 2000Gt of CO2, that is equal to 30% of global soil carbon. However, it has been becoming large CO2 emission source because of peat decomposition and fire due to drainage water. This is caused by social activities such as canalizing. Especially, in Indonesia, peat swamp forests cover considerable portions of Kalimantan and 37.5% of CO2 emission source is peatland (DNPI, 2010). To take measures, it is necessary to conduct appropriate assessment of CO2 emission in broad peat swamp forest.

Because hyperspectral data possess higher spectral resolutions, it is expected to evaluate the detail forest conditions. We develop a method to assess carbon emission from peat swamp forest by using hyperspectral data in Central Kalimantan, Indonesia. Specifically, we estimate 1) forestry biomass and 2) underground water level expected as an indicator of CO2 emission from peat. In this research, we use the image taken by HyMAP which is one of the airborne hyperspectral sensor.

Since the research area differs in forest types and conditions due to the past forest fire and disturbance, forest types are classified with the sparse linear discriminant analysis. Then, we conduct a biomass estimation by using Normalized Difference Spectral Index (NDSI) in each forest type. We also analyze the relationship between underground water level and Normalized Difference Water Index (NDWI), and find the possibility of underground water level estimation with hyperspectral data.

We plan to establish highly developed method to apply hyperspectral sensor to peatland monitoring system.

8527-20, Session 3

The assessment of tsunami damage in Ban Nam Khem, Khao Lak and Thai Mueang, Thailand using IKONOS imagery

Ajira Tiangtrong, Pasu Kongapai, Chulalongkorn Univ. (Thailand)

This research was carried out to investigate the affected areas by the Indian Ocean tsunami on 26 December 2004 in three areas: Ban Nam Khem, Khao Lak and Thai Mueang in Phang Nga Province located in southern of Thailand are the damaged areas which are caused by natural disaster. In this study, the high-resolution (e.g.,IKONOS) satellite images of pre (13 January 2003) and post (26 January 2005) tsunami were used to analyse on the thresholds of the index to indicate surface characteristics with the normalized difference vegetation (NDVI).

The NDVI technique can be used successfully to identify multi-spectral and multi-temporal characteristics each images. Unsupervised classification is gathered to detect tsunami impact from image difference imagery between before and after the tsunami. We can indicate that the classification gave a good differentiation of change detection. The result also allowed us to identify tsunami inundation, severe deteriorated as the infrastructures, mangrove, bare land and aquaculture.

8527-22, Session 3

Remote estimation of nitrogen contents of summer corn leaf by hyperspectral reflectance under rainfed condition

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The objectives of this experiment were to identify sensitive spectral wavelengths, their combinations and spectral vegetation indices (SVIs) that are indicative of nitrogen nutritional condition and to analyze the accuracy of different spectral parameters for remote estimation of nitrogen status temporally. The results showed that there was the best fitting between nitrogen contents and their spectrum parameters at R450, R550, R630, R680, R710 and R550+R710 at 10-12 leaf, followed by silking, tasseling, and early dent stage. The algorithm overall increased the accuracy both in the single and dual waveband. The fittings of the linear regression model constructed by spectra variables (LgR550+LgR720), Lgl 550+R710) and nitrogen contents were the best among them. Spectral ratios in the NIR/Red with R810/
The accuracy of radiance measurements with space-based infrared spectrometers is contingent on the quality of the calibration subsystem, as well as knowledge of its uncertainty. Upcoming climate benchmark missions call for measurement uncertainties better than 0.1 K (κ=3) in radiance temperature for the detection of spectral climate signatures. Blackbody cavities impart the most accurate calibration for spaceborne infrared sensors, provided that their temperature and emissivity is traceably determined on-orbit. The On-Orbit Absolute Radiance Standard (OARS) has been developed at the University of Wisconsin to meet the stringent requirements of the next generation of infrared remote sensing instruments. It provides on-orbit determination of both traceable temperature and emissivity for calibration blackbodies.

The Heated Halo is the component of the OARS that provides a robust and compact method to measure the spectral emissivity of a blackbody in situ. A carefully baffled thermal source is placed in front of a blackbody in an infrared spectrometer system, and the combined radiance of the blackbody and Heated Halo reflection is observed. Knowledge of key temperatures and the viewing geometry allow the blackbody cavity spectral emissivity to be calculated.

We present the results from the Heated Halo methodology implemented with a new Absolute Radiance Interferometer (ARI), which is a prototype space-based infrared spectrometer designed for climate benchmarking. We show the evolution of the technical readiness level of this technology and we compare our findings to models and other experimental methods of emissivity determination.

**8527-26, Session 5**

**Calibration of Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) on the ISS**

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SMILES is a highly-sensitive limb sounder in 640-GHz band on the international space station (ISS). The SMILES measurements of the stratospheric molecules including ozone, ClO, HCl, HOCl, H2O, and BrO were made from October 2009 to April 2010.

The improvement of the radiometric, spectral, and spatial calibrations of these data are discussed in this paper.

The largest error in intensity calibration comes from the receiver gain nonlinearity. The nonlinearity calibration based on the prelaunch measurement was not perfect for the in-orbit instrument condition, which differs from that on the ground. The calibration is improved with in-orbit data. Two measurements from different receiver back-ends but of the same atmosphere are compared and used for updating the nonlinear-correction parameters. This updating of the calibration improves the intensity accuracy of the observed spectra in especially higher altitude, where few data are available from other observations for validating the SMILES data accuracy.

The improvement of the frequency calibration reduces the error of the stratospheric wind estimation from the emission lines. The relative frequency error is reduced to almost a hundredth of the frequency resolution.

The error in the tangent height is another large error source of the SMILES data. The observing-position data are calculated from the attitude data of a nearby instrument in ISS. Because of large structure of ISS, the attitude data from a remote instrument is useless to get an angle resolution less than 1 arcmin.

**8527-27, Session 5**

**Geometry and spectral calibration of pushbroom dispersive hyperspectral imager**

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Development and application of airborne and aerospace hyperspectral imager press for high precision geometry and spectral calibration of pixels of image cube. The paper takes the geometry and spectral calibration of pushbroom dispersive hyperspectral imager as case study, and research on the constitution and analysis of imaging mathematical model. Aimed especially at grating-dispersive hyperspectral imaging, the specialty of the imaging mode and dispersive method has been concretely analyzed. Based on the analysis, the theory and feasible method of geometry and spectral calibration of dispersive hyperspectral imager is set up. The key technique has been solved is As follows:

1. The imaging mathematical model and feasible method of geometry and spectral calibration for full pixels of image cube has been set up, the feasibility of the calibration method has been analyzed.

2. The engineering model and method of the geometry and spectral calibration of pushbroom dispersive hyperspectral imager has been set up and the calibration equipment has been constructed. And the calibration results and precision has been analyzed.

The research of key technique of geometry and spectral calibration of pushbroom hyperspectral imager, its target is giving the coordinate of angle field of view and center wavelength of each detect unit in focal plane detector of hyperspectral imager, and achieves the high precision, full field of view, full channel geometry and spectral calibration. It is importance for imaging quantitative and deep application of hyperspectral imager.

**8527-28, Session 5**

**Calibration of imaging spectrometer based on acousto-optic tunable filter (AOTF)**

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Imaging spectrometer based on acousto-optic tunable filter (AOTF) is a useful high-spectral technology, especially in deep space exploration applications because its characteristics of staring imaging, electronic tunable spectral selection and simple structure. Because the diffraction of light in AOTF filters is dependent on both wavelength and angle of incidence, the Spectral and geometrical calibration must therefore be performed over the entire spectral range of AOTF hyper-spectral imaging systems. In this paper, a method for calibration of acousto-optic tunable filter (AOTF) hyper-spectral imaging systems is proposed and evaluated. And the calibration of a VIS-NIR Imaging Spectrometer (VINS) is introduced by the method. The VINS is a payload instrument for lunar detection and provides programmable spectral selection from 0.45 to 0.95 μm. The results indicates that the method is accurate and efficient. Therefore, the proposed method is suitable for spectral and geometrical calibration of imaging spectrometers based on AOTF.
8527-29, Session 5

The measurement of optical and geometric parameters by a coordinate measuring machine

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Measurements of optical parameters such as radius of curvature (RoC), direction of the optical axis, offset of the apex relative to the outer diameter, et al. of the primary mirror of a Cassegrain telescope by a coordinate measuring machine (CMM) is presented. These parameters are measured by a novel technique developed by the authors. RoC, tilt, and wedge of a lens can also be measured by the technique. Geometric parameters, such as diameters, central obscuration diameter, and perpendicularity of mirror edge, et al. can be measured taking the advantage of the geometric measurement function of CMM. The optical and geometric parameters are measured by this method on a set of primary and secondary mirrors, and four corrector lenses of a Cassegrain telescope. For the primary mirror of a Cassegrain, there is a central obscuration. As a result, radius of curvature at the center cannot be measured even though there are several methods already available for RoC measurement. In addition, it is better to have more clear knowledge on the direction of optical axis of the mirror before the alignment process. Even though there are methods for this, it is not so easy to integrate all the result during the mirror alignment phase. Moreover, if there is tilt and wedge error in the lens, more care shall be taken during the lens alignment especially for double concave or meniscus lenses. It is therefore essential to develop a method to measure the optical and geometric parameters that is accurate enough and easy to be applied. To deal with the above-mentioned demand, a novel technique combining the coordinate measuring machine (CMM) and an optical design and analysis program has been developed. The basic idea of the technique is the fact that the radius is perpendicular to the tangent line at the CMM contact point. With the coordinate information of the sapphire sphere center on CMM and the direction cosine from line at the CMM contact point, one can calculate the coordinate of the contact point by iteration until the presumed curve and the perpendicular condition are met. Through the software, RoC at central point and direction of the optical axis of the mirror can be recorded in the CMM coordinate for later use during integration. Tilt, wedge and center thickness can also be measured by the proposed method.

8527-30, Session 5

On-orbit estimation research of optical system deformation of ZY-3 satellite multispectral camera

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Optical system deformation is one of important factors that affect the interior geometry accuracy of satellite based optical sensor. In this paper, geometry deformation model of optical system is researched, with image simulation technology, using high accurate digital ground ortho-image and DTM, in combination with refined imaging condition which is actually precise orbit and attitude model, so as to estimate the optimal optical system deformation model in imaging field of view through high accuracy matching of simulation image and real image. To verify this, the multispectral camera data is used to analyze the optical system design deformation, laboratory measurements of spectral camera, in comparison with the optical system deformation derived from the algorithm in this paper, it shows coincident trend of deformation curve shape, so validity of the method in this paper is verified. To estimate the optical system deformation, ground ortho-image and DTM in TianJin are used to simulate ZY-3 spectral image, and to evaluate the accuracy of optical system deformation, artificial square diagonal targets in An Ping, He Bei. The experiment shows that: before deformation estimation, the maximum error is 0.5 pixels, with standard deviation 0.2 pixels in ranks directions, while after estimation, maximum error in ranks directions turns to be 0.2 pixels, with standard deviation better than 0.1 pixels, which is equivalent accuracy with that provided by artificial targets. Thus, experiments verified the validity of on-orbit optical system deformation estimation of satellite optical sensor, which is effective to eliminate image interior deformation.

8527-31, Session 6

Radiometric calibration plan for the Hyperspectral Imager Suite (HISUI) instruments

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The Hyperspectral Imager Suite (HISUI) is the Japanese next-generation Earth observation project, which will be onboard ALOS-3 platform. HISUI will be composed of hyperspectral image (185 spectral bands in VNIR-SWIR region with 30 m spatial resolution) and multispectral image (4 spectral bands in VNIR region with 5 m spatial resolution). Radiometric calibration is very important for the accurate higher level products, and the calibration group of HISUI project has the plan of calibration activities, which are onboard calibration, vicarious calibration, cross-calibration, and lunar calibration. Radiometric calibration is indispensable for the accurate higher level products, and the long-term radiometric calibration has a crucial role. On-board calibrator itself has possibilities of degradation, and vicarious calibration is currently the most accurate method to conduct the radiometric calibration of satellite sensors. To increase the frequency for vicarious calibration of HISUI, it is desirable to have as many test sites as possible due to the limited cycle of 60 days. Cross calibration is the useful method in situations where the onboard calibration device is not available and/or vicarious calibration is not feasible. The potential of lunar calibration, namely its feasibility, stability, radiometric uncertainty of the Moon and so on, is also examined. The objective of this research is to establish the techniques and develop the plans for conducting the in-flight radiometric calibration of HISUI with high frequency, reliability, and stability, based on the traditional in-flight radiometric calibration for multispectral sensors.

8527-32, Session 6

Development of onboard fast lossless compressors for multi and hyperspectral sensors

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Fast and small-footprint lossless compressors for multi and hyper-spectral sensors have been developed. The compressors are employed for the multi and hyper-spectral sensors of HISUI (Hyper-spectral Imager SUITE: the next Japanese earth observation project that will be on board Advanced Land Observing Satellite - 3). According to data acquisition process of pushbroom hyper-spectral sensors, compressing methods using spatial correlation require many frame buffers for spatial prediction, and we cannot configure compressor circuits in sufficiently small footprint size.

On the other hand, there are spectral correlations as well as spatial correlations in hyper-spectral sensor data. We have evaluated lossless compression ratios of the images formed by spatial dimensions (CT x AT) and by spatial-spectral dimensions (CT x band) using AVIRIS datasets (29 SWIR bands in Cuprite and 31 VNIR bands in Jasper Ridge) and StarPixel compression, and confirmed that the compression ratios are equivalent (from -1.4% to +2.1%). For multi-spectral sensors, the spectral correlations among the bands are insufficient to improve compression performance. Therefore the image tile formation for multi-spectral compressor of HISUI has been determined to be a spatial (CT) dimension only.

This compression method can achieve the throughput of 30Mpel/sec for hyper-spectral images and 34Mpel/sec for multi-spectral images on a radiation tolerant FPGA (field-programmable-gated-array), which covers the data acquisition throughput of HISUI. We also implemented
the compressor on the evaluation model device of HISUI, and confirmed its feasibility and compression performance of actual hyperspectral sensor data.

8527-33, Session 6

The Geostationary Remote Infrared Pollution Sounder (GRIPS)
Hal J. Bloom, Science and Technology Corp. (United States)

he GRIPS instrument is designed to make remote sensing measurements of key climate and air quality gases from geostationary orbit. Specifically, we are targeting CO2, CH4 and CO. The instrument is a gas filter correlation radiometer that operates in the NIR, SWIR and MWR bands. CO2, CO and CH4 are measured in the SWIR bands using reflected solar IR radiation. CO is also measured in the MWR band to provide measurements over the ocean where the albedo is very low. The instrument also includes measurement channels for N2O in the MWR and O2 A-Band in the NIR. Our strategy is to use N2O and O2-A-Band to estimate changes in photon path length due to cloud and aerosol scattering. These two measurements bracket the wavelengths for the SWIR measurements. Each of the six trace gas measurements is accomplished using a quad telescope system where wavelengths for the SWIR measurements. Each of the six trace gas measurements is accomplished using a quad telescope system where the light from each telescope passes through a target gas cylinder and then onto an imaging detector array. This unique, compact and flexible design allows GRIPS to be accommodated onto almost any GEO platform. Retrieval simulations show that GRIPS will have nearly the same precision as OCO-2 making GRIPS very complementary to that mission.

8527-34, Session 6

Scientific objectives and concept design of a narrow angle camera for Japanese Mars meteorological orbiter
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Mars Meteorological Orbiter and is a proposal to investigate the dust and Martian meteorology and climate, which will be launched 2020 or later. Orbiter instruments will be (1) 15 km resolution wide angle polarization camera, (2) uncooled IR imager, (3) sub-mm sounder, and (4) radio science. A 150 m resolution narrow angle camera is now under trade-off study to be included to the orbiter.

The orbiter will have elliptical equatorial orbit (450 km × 22000 km, i.e. 6.45 km altitude), which will provide 12.3 hours orbit period (or 1/2 Martian day). Polarization camera will give whole disk view (15 km resolution 22000 km altitude) of dust and aerosols by the multi-angle + polarization observation of the dayside. Since the horizontal distribution of Martian dust has several categories in size from ~10 m to several 100 km, a high spatial resolution narrow angle (150 m resolution, 150 km x 150 km or larger IFOV) camera will be necessary to interpret the polarization camera data. Spatial resolution 150 m from the 22000 km altitude is equivalent to 8.8E-6 radian telescope resolution, which is twice worse than MGS/MOC camera, MGS/MOC uses 35 cm primary mirror and 9.5 kg total instrument weight. And this narrow angle camera will be ~17.5 cm and < 5kg total instrument weight including electronics circuits. Measurement strategy, concept optical design, band selection, detector format, spatial coverage, estimated weight, power and data rate will be reported.

8527-35, Session PSWed

Kenta Ogawa, Makoto Takenaka, Rakuno Gakuen Univ. (Japan); Tsuneo Matsunaga, Satoru Yamamoto, National Institute for Environmental Studies (Japan); Osamu Kashimura, Tetsushi Tachikawa, Japan Space Systems (Japan); Satoshi Tsuchida, National Institute of Advanced Industrial Science and Technology (Japan); Jun Tanii, Japan Space Systems (Japan); Shuichi Rokugawa, The Univ. of Tokyo (Japan)

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 2015 or later. In HISUI project, Operation Mission Planning (OMP) team has responsibility to make long term and short term the observation planning strategy. OMP is important for HISUI especially for hyperspectral sensor, and the relationship between the limitations of sensor operations and the possible observation plan have to be studied. Major factors of the limitations are the combinations of downlink rate, observation time (15 minutes per orbit) and the swath of the sensor (30 km). The achievements of global mapping or regional monitoring will need to be simulated precisely before launch. We have prepared daily high resolution (30 second in latitude and longitude) cloud data for the simulation. Monthly cloud statistics will be useful for making effective observation plans.

8527-38, Session PSWed

Effect of particle size on prediction of soil TN with remote sensing based on NIR spectroscopy
Xiaofei An, Minzai Li, Lihua Zheng, Yumeng Liu, China Agricultural Univ. (China)

Soil total nitrogen (TN) is one of the most important soil parameters. It is a feasible method to detect soil TN content with remote sensing based on NIR spectroscopy. But the accuracy of soil TN model established by the NIR spectroscopy method was affected seriously by soil particle size. In this work, different particle size soil samples were scanned by MATRIX F Fourier spectral analyzer. The effect of soil particle size on prediction of soil TN was discussed from the qualitative analyses and quantitative analyses. The spectral scanning results showed that at the same soil TN content level, with the decrease of the soil particle size, the reflectance of soil samples was reduced and the trend was not linear relationship. At the short wavelength (760-1100 nm) wave bands, there were a little of differences; while at the long wavelength (1100-2500 nm) wave bands, there were great differences. Two methods were adopted to eliminate the effect of soil particle size. The first method was to establish TN model by the first order differential preconditioning method of the spectral data. The correlation coefficient of calibration (Rc) was 0.98 and RMSEC was 0.012. The validation experimental samples were preprocessed to diameter of 0.9, 0.45, 0.3 and 0.2 mm respectively. The correlation coefficient of validation (Rv), RMSEP and RPD for different dataset were 0.6, 0.062, 1.548; 0.68, 0.052, 1.838; 0.55, 0.063, 1.532 and 0.76, 0.046, 2.026 separately. Compared with the established model by using the original spectral data, the model accuracy was improved significantly. The second method was to establish TN model with different particle size soil samples after preprocessing. Rs and RMSEC of the predicting model were 0.92 and 0.025. And the Rs, RMSEP and RPD for different validation dataset with diameter of 0.9, 0.45, 0.3 and 0.2 mm soil samples were 0.76, 0.042, 2.921; 0.76, 0.043, 2.851; 0.78, 0.049, 2.66 and 0.78, 0.035, 3.246. Through the combination of the two methods, the effect of soil particle size on prediction of soil TN can be eliminated effectively.

8527-39, Session PSWed

Monitoring of maize chlorophyll content based on multispectral vegetation indices
Hong Sun, Minzai Li, Lihua Zheng, Yane Zhang, China Agricultural Univ. (China); Yajing Zhang, Editorial office of Transaction of CSAM, CAAMS, Beijing 100083, China (China)

It is necessary for precision agriculture to understand the spatial-temporal variability and real-time nutritional status of field crop. As rapid, convenient and nondestructive techniques, multispectral image technique provides accurate and scientific data for precision agriculture. In order to detect the nutrient status of maize, the multispectral images of maize canopy were collected in the field located at Shangzhuang Experiment Station on the north of Beijing, and the corresponding chlorophyll content of each sample was measured in
these parameters had the potential as water stress indicators. More green and red channel. Based on the analysis of the acquired images, sensor which could output images in spectral bands of Near-infrared, identify the causes of stress. The images were taken by multi-modal sensory data to improve plant stress detection and could further be used as a decision support system that combines problems. The core technology of this multi-modal sensor system water stress levels. This research aims at solving the aforementioned grape canopy from its reflectance features, and identify the different multi-modal sensor system was designed to measure the reflectance signature of grape plant surfaces and identify different water stress levels in this paper. The multi-modal sensor system was equipped with two sensors: one 3CCD camera (three channels in R, G, and IR) and a multispectral camera (covering the spectral bands at 900 nm and 970 nm). The multi-modal sensor can capture and analyze grape canopy from its reflectance features, and identify the different water stress levels. This research aims at solving the aforementioned problems. The core technology of this multi-modal sensor system could further be used as a decision support system that combines multi-modal sensory data to improve plant stress detection and identify the causes of stress. The images were taken by multi-modal sensor which could output images in spectral bands ofNear-infrared, green and red channel. Based on the analysis of the acquired images, reflectance features based on spectroscopy and color features based on RGB color space were calculated. The results showed that these parameters had the potential as water stress indicators. More experiments and analysis are needed to validate the conclusion.

8527-41, Session PSWed
Comparing the new generation WorldView-2 to hyperspectral image data for species discrimination
Khalid Mansour, Onisimo Mutanga, Univ. of KwaZulu-Natal (South Africa)
 Discriminating indicator species in mountainous rangelands is critical for better understanding the extent of the rangeland and their levels of degradation. The objective of this study was to compare whether canopy reflectance spectra, resampled to WorldView-2 and HyMap resolution could discriminate four increaser species representing different levels of rangeland degradation. Canopy spectral measurements were taken from the four indicator species: Hyparrhenia hirta, Eragrostis curvula, Sporobolus africanus, and Aristida diffusa. The random forest algorithm and a forward variable selection method were applied in order to identify optimal variables (HyMap and WorldView-2 wavelengths) for discriminating among the species. Results revealed that 8 optimal wavelengths from HyMap and 6 from WorldView-2 yielded the lowest OOB error (15.82%) and (17.36%) for HyMap and WorldView-2, respectively, in discriminating among the four increaser species. The random forest algorithm could discriminate species with an overall accuracy of 84.1% (KHAT = 0.79) using HyMap wavelengths and an overall accuracy of 82.9% (KHAT = 0.77) using the WorldView-2 wavelengths. Overall, the study demonstrated the potential of WorldView-2 in terms of cost effectiveness compared to HyMap data for mapping indicator species of rangeland degradation.

8527-42, Session PSWed
A PIF-based relative radiometric normalization method for multitemporal remote sensing images
Xia Zhang, Institute of Remote Sensing Applications (China)
Change detection of land cover by using remote sensing time series is a powerful application that has seen increasing applications, as remote sensed imagery has become more widely available and inexpensive. Before a time series of remotely sensed imagery are used for change detection, they have to be firstly be standardized for effects except real surface change. This paper proposed an improved pseudo-invariant features method to normalize temporally separate but spatially coincident imagery. Using the concept of pseudo-invariant features between master-slave image pairs, spatially coincident urban features are identified with difference thresholds from images; then these features were filtered using principal component analysis, their quality was controlled through correlation coefficients; finally a regression equation was calculated using robust orthogonal regression to normalize the slave images to the master one. This improved method was verified by Beijing-1 satellite images. The results indicated that, benefiting from the use of objective statistical characteristics of sampling points, this method could overcome the defect of subjective sampling and improved the normalization accuracy. Therefore it will guarantee further effective extraction of land use/cover change information.

8527-43, Session PSWed
Object-oriented high-resolution and multispectral remote sensing image information extraction of urban green space based on support vector machine
Xuerong Li, Qianguo Xing, Yantai Institute of Coastal Zone Research (China); Chao Xu, South China Sea Institute of Oceanology (China)
Urban green space plays a very important role in urban planning, environmental protecting, sustainable development and etc. High-resolution remote sensing images such as SPOT 5 have detailed spectrum, texture and space structure information, while multispectral ETM images have more abundant spectral information. Choose Yantai City as a research region, and classify urban green space
to production green space, protection green space, public green space, road green space and other objects. First, precise geometric corrections of SPOT 5 images and ETM images are performed and their fusion images are produced. Then execute multi-level and multi-scale object or plaques segmentation to extract the object features such as spectral, texture, and space structure information. Implement support vector machine (SVM) classifier based on LIBSVM and choose radial basis function as kernel and select the appropriate parameters. With object features input, SVM training is executed. Finally, the trained SVM is used for image classification. The method is fully utilized the image spectrum, texture and space structure information and can effectively improve the accuracy of the extraction of urban green space, relative to the traditional pixel-based extraction method.

8527-44, Session PSWed

Development of a portable spectroscopy-based device to detect nutrient status of apple tree
Yao Zhang, Lihua Zheng, Minzan Li, Xiaolei Deng, Xiaofei An, China Agricultural Univ. (China)

Nitrogen is one of the most important nutrition elements in apple tree growth process so that diagnosis of nitrogen level has become the emphasis of agronomy research. In order to detect apple tree growth status fast and accurately, a portable spectroscopy-based device was developed. The instrument uses an ARM9 as the Micro Controller Unit (MCU). It consists of an optical system and a control system. The optical system includes an optical source, a commutation and force driving-circuit, a Y-type optical fiber used for incidence and reflectance, a probe and a photoelectric sensor. The control system includes amplified circuit, A/D transferring circuit, display circuit with LCD (Liquid Crystal Display) and storage circuit with USB (Universal Serial Bus) disk. The light sources are connected with the incidence channel of Y-type fiber and three wavebands of light source were used in the detector, which include green, red and NIR band. The optical signal is transferred to the surface of the target leaf via the incidence fibers, and then the reflected optical signal is collected and transferred to photoelectric sensor where the optical signal is transferred into electric signal. After acquiring the electrical signal, the control system carries out the processes of signal magnification filter and A/D conversion. Subsequently, the signal is inputted to the leaf nitrogen detecting model and calculated. Finally, the nitrogen content is displayed and stored. The experiments showed that the correlation coefficient between the measured nitrogen content and the detected nitrogen content reached 0.886. It illustrated that the apple tree nitrogen detector is practical and can be used to detect leaf nitrogen in apple orchard.

8527-45, Session PSWed

The growth forecasting model for apple tree based on ground-based remote sensing
Ronghua Ji, Lihua Zheng, Xiaolei Deng, Yao Zhang, Hong Sun, Minzan Li, China Agricultural Univ. (China)

In order to realize non-destructive monitoring the growth for apple trees effectively, the spectra of apple leaves were collected with ground-based remote sensing and the relationship between the apple leaf spectral reflectance and the apple growth parameters was analyzed. Firstly 25 apple trees planted in an orchard at the outskirts of Beijing were selected and then one branch toward sun of each apple tree was fixed as research branch. Then leaves were collected from the base, middle and top of each research branch at 5 different stages of apple tree annual growth cycle. The visible and near infrared spectral reflectance of the collected leaves were measured by the spectrogaph (UV/Vis, Shimadzu). At the same time, the corresponding chlorophyll content (LCC), the leaf moisture content (LMC) and leaf area index (LAI) which were used to represent the apple tree growth status were measured in the laboratory.

In order to find the optimal spectral bands, the transformation forms of spectra, which were first derivative, second derivative, reciprocal, logarithm, the logarithm of reciprocal and the first derivative of logarithm, were calculated. The correlation between the apple leaf spectra (original spectra and its transformation forms) and the apple tree growing parameters (LCC, LMC and LAI) were analyzed. The result showed that the first derivative of spectra was most correlated with chlorophyll content in apple leaves from 550nm to 620nm; the logarithm of reciprocal was most correlated with LMC in apple leaves from 670nm to 720nm; the reciprocal and first derivative were most correlated with LAI in apple leaves from 320nm to 350nm. Accordingly three apple tree growth forecasting models were built based on the selected sensitive bands by using multiple linear regression analysis (MLR), principal component analysis (PCA) and artificial neural network (ANN) respectively. The result showed that the forecasting model based on PCA was the optimal model to predict the apple leaves chlorophyll, and its calibration R2 was 0.831 and validation R2 was 0.794. The apple leaves nutrient content forecasting model based on ANN was optimal, and its calibration R2 was 0.8561 and validation R2 was 0.734. The apple leaf area index forecasting model based on PCA was best, and its calibration R2 was 0.8712 and validation R2 was 0.811.

8527-46, Session PSWed

Analysis of soil phosphorus concentration based on Raman spectroscopy
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Adequate soil Phosphorus availability for plants stimulates early plant growth and hastens maturity. However mismanagement of soil Phosphorus can pose a threat to water quality and cause algal bloom and eutrophication. It is time consuming and labor intensive approach when we detect the phosphorus concentration by utilizing the standard chemical and laboratorial assessment. However, based on vibrational transitions of irradiated molecules, Raman spectra signature can provide structural information that is often suitable for sample identification. The Raman spectrum depends on the masses of the atoms in the molecule, the strength of their chemical bands and the atomic arrangement. Consequently, different molecules have different vibrational Raman spectra. Furthermore, soil moisture does not generally interfere with Raman spectral analysis as it has done to UV, VIS and NIR spectra.

Phosphate ions generally react by adsorbing to soil particles or by combining with elements in the soil such as calcium (Ca), magnesium (Mg), aluminum (Al), and iron (Fe), and forming compounds that are solids. It is important to make the soil samples according the real soil properties by addressing the main research target but eliminating most other affecting factors. In this work, based on Raman spectroscopy, in order to discover the quantity reflecting mechanism of soil phosphorus concentration to the Raman signature, 15 soil samples with different phosphate and content were made in laboratory and their Raman signatures were measured. The relationship between sand soil Phosphorus concentration and soil Raman spectra was explored. Then the effective Raman signal were extracted from the original Raman spectra by using bior4.4 wavelet packet, and the relationship between sand soil phosphorus and their extracted signals was analyzed and the PLS model for predicting phosphorus concentration was established and compared based on the original Raman signatures and the extracted effective Raman signals. The maximum accuracy model comes from the extracted effective Raman spectra after the first level decomposing. The calibration R2 was close to 1 and the validation R2 reached to 0.937 and it showed high soil phosphorus detecting potential by using Raman spectroscopy.

8527-47, Session PSWed

Estimation of tomato leaf nitrogen content using continuum-removal spectroscopy analysis technique
Yongjun Ding, Minzan Li, Lihua Zheng, Hong Sun, China Agricultural Univ. (China)

In hyperspectral remote sensing, noises and background interference always degrades the accuracy of spectral feature extraction. Continuum-removal analysis enables separating the interested absorption spectral features, hence more sensible absorption features can be abstracted and the determination coefficient can be improved.
significantly. The purpose of this study was to test continuum-removal methodology with visual-NIR spectral data of tomato leaf. Through analyzing the correlation between continuum-removal spectra of samples and their corresponding nitrogen contents, 15 characteristics parameters which showed ability to change tendency of nitrogen content were chosen, which were at 335, 405, 500, 520, 540, 550, 560, 580, 620, 640, 683, 704, 720, 736 and 770 nm respectively. Finally, the variance analysis and stepwise regression method was used to develop the prediction model of the nitrogen content of tomato leaf. The result showed that the higher predictive ability came from the predicted model based on continuum-removal spectra and using 335 and 720 nm as independent variables. Its R2 reached 0.755, and the root mean square error of prediction using a leave-one-out cross validation method was 0.513. These results indicate that the continuum-removal spectroscopy analysis has better potential to diagnose tomato growth level.

8527-48, Session PSWed
**Predicting apple tree leaf nitrogen content based on hyperspectral applying wavelet and wavelet packet analysis**
Yao Zhang, Lihua Zheng, Minzan Li, Xiaolei Deng, Hong Sun, China Agricultural Univ. (China)
Nitrogen plays an important role in nutrient elements of apple trees. It has become the emphasis of agronomy research to achieve monitoring nitrogen for apple tree in real-time and nondestructive since it can help farmers applying fertilizers properly and reducing environmental pollution. In this study, the visible and near infrared spectral reflectance were measured for apple leaves by using Shimadzu UV-2450 spectrophotograph in fruit-bearing period, fruit-falling period and fruit-maturing period respectively, and the nitrogen content of each apple tree leave sample was measured in the laboratory. The analysis of correlation between nitrogen content of apple tree leaves and their hyperspectral data was conducted. Then the low frequency signal and high frequency noise reduction signal were extracted by using wavelet packet decomposition algorithm. And then the principal components spectra were collected after conducting principal component analysis. Finally two multiple linear regression models were established based on low frequency principal components spectra and noise reduction principal components spectra separately. After comparing, it was known that the model built based on noise reduction principal components spectra had higher accuracy than the other one in fruit-bearing period and physiological fruit-maturing period. Their R2 reached 0.9529 and 0.9501, and validation R2 reached 0.7285 and 0.7303 respectively. While in the fruit-falling period the model based on low frequency principal components spectra had the highest accuracy, and its calibration R2 reached 0.9921 and validation R2 reached 0.6234. The results showed that according to different physiological phases, the optimal model can be built based on different preprocessed spectra, and it illustrated that it was an effective way to improve ability for predicting apple tree nitrogen content based on hyperspectral analysis by using wavelet packet algorithm.

8527-49, Session PSWed
**Optical discrimination of harmful algal species based on hyperspectral reflectance in the East China Sea: model results**
Bangyi Tao, Zhihua Mao, The Second Institute of Oceanography, SOA (China)
A hyperspectral approach is explored to discriminate the two species of Skeletonema costatum and Prorocentrum donghaense Lu from remote sensing reflectance. The spectra of reflectance are simulated by the model of HydroLight 5.0 using actual specific coefficients as input. Due to the spectral overlap, it is potentially difficult to distinguish the two species from specific absorption spectra, but their scattering properties have quite different spectral behaviors, especially in the red bands. Our modeling of a comprehensive reflectance data set for various concentrations confirms the potentials offered by the characteristics of hyperspectral reflectance in the red region to identify the bloom species. The ratio of the maximum reflectance in red part to chlorophyll concentration is considered as a robust index to differentiate the algal specie from each other. Furthermore, the different relationship between the peak position and chlorophyll concentration can also be used.

8527-50, Session PSWed
**Retrieving the oil and gas microleakage information using the hyperspectral data**
Sihong Jiao, Beijing Vocational and Technical Institute of Industry (China)
In hyperspectral remote sensing, the increase of the channel also increased the difficulty of choose effective band. To solve the issues of the correlation between different spectrum band and that between dependent variables, this paper proposed a partial least squares (PLS) regression model to predict the content of acid hydrolysis hydrocarbon which is migrated by microleakage from oil and gas reservoir. In the proposed PLS model, the 41 bands on the second derivative data of hyperspectral reflectance are selected as independent variables and 8 variables of Acid hydrolysis hydrocarbon are used as response variables. The preliminary results showed that the proposed method can effectively retrieve microleakage quantitative information from weak information, under the conditions that high dimensional data and multi-observation variable are available. Compared with the traditional single variable regression, the inversion results have better improvement borrowing consideration on the relationship between multi-variables. The validation result of the PLS model indicates that PLS model can reduce the correlation of hyper-spectral bands and thus to improve the prediction performance of oil and gas microleakage, and it is a promising method to quantitatively retrieve the microleakage hydrocarbon information from the weak information contented data. In the further research, the proposed method can be used as an efficient way in prospecting the oil and gas microleakage information from remotely sensed data.

8527-51, Session PSWed
**The Cross-track Infrared Sounder (CrIS) on Suomi NPP: expected radiometric and spectral performance and calibration/validation results: part II**
Daniel H. DeSloover, Henry E. Revercomb, David C. Tobin, Robert O. Knuteson, Joe K. Taylor, Graeme Martin, Raymond K. Garcia, Lori Borg, Univ. of Wisconsin-Madison (United States)
Post-launch evaluation of the CrIS instrument was used to study radiometric non-linearity and spectral calibration. Updated non-linearity coefficients were derived using FOV-to-FOV analyses of normal mode Earth view data. Inter-FOV studies were also used to obtain spectral shifts relative to the center (FOVs) for each of the three spectral bands (LW, MW and SW). In-house processing using the CrIS Calibration Algorithm and Sensor Testbed (CCAST) and the Algorithm Development Library (ADL) software were utilized to independently verify our findings.

8527-52, Session PSWed
**Parallel evaluation for detector devices of the hyperspectral imager with a supercontinuum source**
Yu Yamaguchi, Juntaro Ishii, Yoshiro Yamada, National Metrology Institute of Japan (Japan)
The first Japanese earth observing hyperspectral/multispectral imager mission, the HISUI (Hyper-spectral Imager SUlte) mission, is currently underway. The HISUI hyperspectral sensor will have 185 bands, 57 of which are in the visible and the near infrared and the remaining 128 in the short wavelength infrared, covering the spectral range from 400 nm to 2.5 μm. In order to guarantee the observed data with its high spatial and wavelength resolution, it is necessary to evaluate the difference of the spectral sensitivity among the detector
UAV-based observation schemes will be presented. Land vegetation and atmospheric monitoring from both ground- and small UAV platforms. Several remote sensing applications including small weight of 600 g, the NH-1 system can easily be installed on a wavelength range of 350 - 1050 nm, with a spectral resolution of 5 nm. Because of its internal self-scanning system, the imager covers a wavelength range that enabled the development of small hyperspectral imaging systems. Recent advances in image sensor and information technologies have enabled the development of small hyperspectral imaging systems.

EBA JAPAN (Tokyo, Japan) has developed a novel grating-based, hyperspectral portable video camera remote sensing applications with NH-1 enabled the development of small hyperspectral imaging systems. The imager covers a wavelength range of 350 - 1050 nm, with a spectral resolution of 5 nm. Because of its internal self-scanning system, the imager covers a wavelength range that enabled the development of small hyperspectral imaging systems.

Many studies illustrated that the variations of plant canopy spectral reflectance are highly related to leaf chlorophyll content, moisture content, organizational structure and leaf layer structure. In order to detect the temporal and spatial variation of spectral characteristics in apple orchard, the experiments were carried out continuously from April to October in 2011 in the apple orchard located in Xiangtang Village in Beijing. Firstly the flower/leaf samples from 15 year-old trees and 5 year-off trees were collected and a main branch of each tree was marked to represent the growing status of the tree. The real time reflectance spectra of flowers/leaves from three parts (base, middle, top) of each main branch were measured by using the ASD spectrometer and some samples from these three parts were collected and their absorbance were acquired by using a spectrophotometer in lab, as well as their moisture content, chlorophyll content and nitrogen content were measured in lab. And then the temporal and spatial variations of spectral characteristics were analyzed. The results showed that leaves from the top of the branch had higher reflectance and lower moisture content than the other parts of the branch at the same time. As time passed by, the moisture content and the nitrogen content of the leaves have decreased in general. However the leaf chlorophyll content has been changing all the time and the spectra showed variational characteristics. The reflectance spectra of apple trees changed significantly at different stages. Furthermore, the reflectance spectra varied in different parts of the apple trees as well as in different trees. Accordingly the temporal curve and spatial figure were obtained and the growing information can be analyzed from them.

Remote sensing applications with NH-1 hyperspectral portable video camera
Yohei Takara, EBA Japan Co. Ltd. (Japan); Naohiro Manago, Hayato Saito, Yusaku Mabuchi, Akihiko Kondoh, Chiba Univ. (Japan); Takahiro Fujimori, Fuminori Ando, EBA Japan Co. Ltd. (Japan); Makoto Suzuki, Japan Aerospace Exploration Agency (Japan); Hiroaki Kuze, Chiba Univ. (Japan)
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Temporal and spatial variation of canopy spectral characteristics in apple orchard
Xiaolei Deng, Minzan Li, Lihua Zheng, Yao Zhang, China Agricultural Univ. (China)
Plant nutritional status can be evaluated with remote sensing. Many studies illustrated that the variations of plant canopy spectral reflectance are highly related to leaf chlorophyll content, moisture content, organizational structure and leaf layer structure. In order to detect the temporal and spatial variation of spectral characteristics in apple orchard, the experiments were carried out continuously from April to October in 2011 in the apple orchard located in Xiangtang Village in Beijing. Firstly the flower/leaf samples from 15 year-old trees and 5 year-off trees were collected and a main branch of each tree was marked to represent the growing status of the tree. The real time reflectance spectra of flowers/leaves from three parts (base, middle, top) of each main branch were measured by using the ASD spectrometer and some samples from these three parts were collected and their absorbance were acquired by using a spectrophotometer in lab, as well as their moisture content, chlorophyll content and nitrogen content were measured in lab. And then the temporal and spatial variations of spectral characteristics were analyzed. The results showed that leaves from the top of the branch had higher reflectance and lower moisture content than the other parts of the branch at the same time. As time passed by, the moisture content and the nitrogen content of the leaves have decreased in general. However the leaf chlorophyll content has been changing all the time and the spectra showed variational characteristics. The reflectance spectra of apple trees changed significantly at different stages. Furthermore, the reflectance spectra varied in different parts of the apple trees as well as in different trees. Accordingly the temporal curve and spatial figure were obtained and the growing information can be analyzed from them.

Scattering properties of two blooming algae: Skeletonema costatum and Prorocentrum donghaiense
Yuzhang Shen, Zhihua Mao, Bangyi Tao, The Second Institute of Oceanography, SOA (China)
A method based on spectrometer was developed to measure the total scattering and backscattering coefficient of algae containing solution. The method correction procedure was carried out by measuring the scattering results of polystyrene latex micro beads with known size distribution and refractive index. The results show a maximum deviation of 4% for scattering in the visible spectrum and around 20% higher for backscattering in the red spectrum but quite good consistency in other regions. The method was then used to measure the scattering and backscattering features of two bloom algae in East China Sea: Skeletonema costatum and Prorocentrum donghaiense. It shows that the two algae have comparable amplitude in both scattering and backscattering cross section, but Skeletonema costatum has a quite opposite scattering pattern from Prorocentrum donghaiense, whose scattering decreases with increasing wavelength. This could be attributed to the different cellular components. Both algae have a regional minimum of scattering around 670nm, which is due to the anomalous dispersion and the strong absorption of chlorophyll a. The backscattering cross section for the two algae are similar in both amplitude and spectrum pattern, Prorocentrum donghaiense has a higher but smoother backscattering spectrum. It’s demonstrated that the backscattering spectrum is well influenced by absorption of cellular pigments. Finally, the backscattering to scattering ratio is 0.723% for Skeletonema costatum and 1.104% for Prorocentrum donghaiense.

8527-53, Session PSWed
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8528-1, Session 1

Sentinel-1 system overview and performance (Invited Paper)
Dirk Geudtner, European Space Research and Technology Ctr. (Netherlands)

In the framework of the EU/ESA co-funded Global Monitoring for Environment and Security (GMES) program, the European Space Agency (ESA) is undertaking the development of a series of five Sentinel missions with the objective to provide routinely Earth observation data for the implementation of operational GMES and national services.

As part of the GMES Component, the Sentinel-1 (S1) mission is based on a constellation of two satellites (i.e. A and B units) each carrying an imaging C-band SAR instrument providing data continuity of ERS and ENVISAT SAR types of mission.

The Sentinel-1 end-to-end system, including both satellites and the ground segment, is specifically designed to acquire systematically and provide routinely data and information products for GMES Ocean, Land and Emergency services. These cover operational applications such as the observation of the marine environment, including oil spill detection and sea-ice monitoring, the surveillance of maritime transport zones, as well as the mapping of land surfaces including vegetation cover (e.g. forest) and in support of disaster and crisis situations.

In addition, the 12-day repeat orbit cycle of each satellite and the maintenance of the orbital deviation within a tube of 50m radius (RMS) enable SAR interferometry (InSAR) coherent change detection applications such as monitoring of surface deformations and cryosphere dynamics.

The paper provides an overview of the Sentinel-1 system characteristics including the SAR instrument and its imaging modes, the SAR interferometry capabilities, and the specifics of related attitude and orbit control modes (i.e. roll steering mode and zero-Doppler steering mode). Furthermore, the paper outlines the planned Sentinel-1 commissioning phase activities related to the in-orbit SAR system end-to-end performance verification and calibration.

8528-2, Session 1

The development status of EarthCARE
Robert V. Gelthorpe, European Space Research and Technology Ctr. (Netherlands)

The EarthCARE satellite is due for launch in 2015 and is intended to study the interactions of clouds, aerosols and the earth’s radiation budget. It is developed jointly by ESA and JAXA. Its payload will consist of four instruments: an atmospheric lidar (ATLID), a cloud profiling radar (CPR), a multi-spectral imager (MSI) and a broad-band radiometer (BBR). The four instruments will operate both stand-alone and in synergy to produce a diverse range of products which include vertical profiles of aerosols, liquid water and ice on a global scale, observations of cloud distribution and vertical motion within clouds, and, by using cloud and aerosol data will allow the retrieval of profiles of atmospheric radiative heating and cooling.

The presentation will describe the satellite and payload configuration and development status. It will focus in particular on the performance requirements and realisation of the four payload instruments. Areas of activity which have given rise to developmental difficulty will be addressed. Currently available test results will be presented for each of the instruments and the presentation will be illustrated by use of diagrams and photographs of existing hardware.

8528-3, Session 1

CMOS sensor for RSI applications
Bill Wang, Shengmin Lin, CMOS Sensor Inc. (United States)

Three CMOS sensors were developed for remote sensing instrument (RSI) applications. First device is linear CMOS Sensor for Terrain mapping camera (TMC). This device has 4000 elements, 7 µm × 7 µm of pixel size. Second device is area CMOS Sensor for Hyper Spectral Imager (HySI). The device has 512 × 256 elements and 50 µm × 50 µm of pixel size. Third device is multi band sensor for remote sensing instrument. This device used our proprietary wafer bumping technology to integrate five linear CMOS sensor into a single monolithic chip. The multi band sensor consists of one panchromatic (PAN) and four multi-spectral bands (B, G, R, and NIR). The PAN is 12000 elements, 10 µm × 10 µm with integration time of 297 µs ± 5%. Each MS band is 6000 elements, 20 µm × 20 µm with integration time of 594 us ± 5%. The spacing between each band to its adjacent band is 4 mm.

Both linear and area CMOS sensor were designed and developed for Chandrayaan-1 project. The Chandrayaan-1 satellite was launched to the moon on October 22, 2008. The moon orbit height is 100 km and 24 km of swath size. The multi band sensor was design for earth orbit. The earth orbit height is about 720 km and 24 km of swath. The low weight, low power consumption and high radiation tolerance requirement only can be done by CMOS Sensor technology. The detail device structure and performance of three CMOS sensors will be present.

8528-4, Session 1

An assessment of Ozone Mapping and Profiler Suite (OMPS) limb sensor performance and calibration
Glen Jaross, Grace Chen, Michael Haken, Mark Kowitt, Nick Gorkavyi, Science Systems and Applications, Inc. (United States); Philippe Xue, Science Applications International Corp. (United States); David Fittner, NASA Langley Research Ctr. (United States)

Following the October, 2011 launch of the Suomi National Polar-orbiting Partnership (NPP), the Ozone Mapping and Profiler Suite (OMPS) began collecting data on November 6. The Suite is comprised of two nadir-viewing sensors and a limb-viewing sensor. The Nadir sensors were designed as successors to the Solar Backscatter and Ultraviolet (SBUV2) and Total Ozone Mapping Spectrometer (TOMS) series of instruments, and the Nadir Mapper was patterned after the instruments. The OMPS Limb Profiler carries on the limb scatter data records of the SAGE III, OSIRIS and SCIAMACHY instruments, but has a unique imaging design that has never before been used in an operational instrument.

Initial limb sensor measurements were designed to characterize dark currents and detector linearity, and to investigate transients caused by charged particles. The results of these evaluations, summarized in this presentation, revealed no unexpected behavior. Analysis of data collected after the start of permanent Earth viewing observations on January 26, 2012 has confirmed the adequacy of the sensor design. The 4 orders of magnitude in Earth radiances lead to substantial levels of internally scattered stray light, yet a combination of hardware and software mitigations leaves at most 2% stray light errors in the final radiances product. Another key performance characteristic, sensor pointing knowledge, has met with less success. An unanticipated thermal sensitivity has invalidated the pre-launch pointing vectors, though a variety of in-flight measurements have allowed the recovery of much of the information.
OMPS Nadir early on-orbit performance evaluation and calibration

Chunhui Pan, Univ. of Maryland, College Park (United States); Fuzhong Weng, xianggian wu, NOAA/NESDIS (United States); Matt Kowalowski, USRA (United States); Glen Jaross, SSAI (United States); Larry Flynn, NOAA/NESDIS (United States)

NPP OMPS was launched on October 28, 2011 and opened its nadir aperture door on Jan. 26, 2012, beginning its Earth observing mission. It continues the US program for monitoring the Earth’s ozone layer using advanced hyperspectral instruments that measure sunlight in the ultraviolet and visible backscattered from the Earth's atmosphere. OMPS is a push-broom instrument suite with a 110-degree cross-track Field of View (FOV) telescope. The onboard calibrators Light-emitting diode (LED) provides linearity calibration and Reflective solar diffuser maintains calibration stability through periodic solar observations. The degradation of the working solar diffuser is tracked using a reference solar diffuser. In this paper, we present OMPS Nadir early on-orbit results from solar, LED, dark and bias calibration and characterization, discusses the main performance and calibration features and results. Examples of the sensor’s short-term and limited long-term responses are presented to illustrate the sensor s on-orbit stability and overall sensor performance.

COMS MI visible channel responsivity trend monitoring

Kyung-Wook Jin, Bong-Kyu Park, Seok-Bae Seo, Korea Aerospace Research Institute (Korea, Republic of)

COMS (Communication, Ocean and Meteorological Satellite) was successfully launched at 21:41 UTC on the 26th of June, 2010 (6:41am, June 27, 2010 in Korea) and has been providing well-calibrated scientific data via a near real-time satellite broadcasting system. To generate valuable data to user groups and science community, stringent monitoring of the data quality with proper calibration processes is crucial. Unlike the calibration of the infrared channels of COMS MI (Meteorological Imager), that of the visible channel is primarily conducted using a vicarious method. On the other hand, COMS MI infrared channels use a black-body target along with the cold target of a space look (2.7K cosmic background) to calibrate infrared measurements. In addition, the GOCI (Geostationary Ocean Color Imager), which is another scientific payload equipped on the COMS, use a solar diffuser as an onboard calibration target.

To monitor the calibration accuracy of the visible channels of MI, two methods are used. First, ROLO (Robotic Lunar Observatory) model-based lunar calibration is employed to accurately measure the long-term degradation of the visible detectors. Several Earth observation satellite missions such as SeaWIFS (Sea-viewing Wide Field-of-view Sensor) showed promising results of the lunar calibration. It was reported that the ROLO model has a capability of relative sensor response trend with precision of 0.1% per year. For the lunar calibration, the MI sensor needs to take several Moon images (nominal or special observations) during the operation. Each month at least one Moon image is required to trend the responsivity of the visible channel. Second, the on-board device called “albedo monitor” is used to monitor the stability of the visible channel as a supplementary tool. This albedo monitoring method has limitation to estimate the total degradation of the instrument due to the use of a partial aperture rather than a full aperture.The albedo monitor embedded in the Imager acquires the Sun image about 6:30am (local time) every day. The albedo monitor captures one Sun or dual Sun images depending on the solar declinations, which corresponds to the date of the year at the albedo image acquisition.

In this talk, the implementations of the two calibration methods (Lunar calibration and albedo monitoring method) of the MI visible band would be addressed with analyses results during the COMS IOT (In-Orbit Test) and a normal operation period.

Long-term calibration monitoring of medium resolution spectral imager (MERSI) onboard FY-3

Xiuqing Hu, Ling Sun, Na Xu, Lin Chen, China Meteorological Administration (China)

Medium Resolution Spectral Imager (MERSI) is an instrument onboard Fengyun-3 (FY-3), the second generation of polar-orbiting meteorological satellites in China. MERSI has nineteen solar reflective bands (RSB) with center wavelengths from 0.41 to 2.1 & #956;m and one thermal emissive band (TEB) with center wavelength 12 & #956;m. Its spatial resolutions are 250 meters (bands 1-5) and 1 km (bands 6-20), respectively. MERSI is a cross-track scanning spectroradiometer with a wide scan swath and provides a complete global coverage of the Earth twice a day. This instrument has run on-orbit for more than three years since it was launched May, 2008. The RSB bands are calibrated using a Visible Onboard Calibrator (VOC). Through a continuous monitoring of the VOC, it is found that the MERSI has a significant degradation on the order of 10% in some bands, with the largest in band 8 of about 20% during the past two years in its shorter RSB bands (<500nm) and the performance at longer wavelength bands is relatively stable with a change less than 5% during the two years. It is shown that the post launch calibration slope of the two SWIR bands has a frequent fluctuation because of random jumps in their electronic gains. These results are consistently verified by several kinds of vicarious calibration (VC) methods: China Radiometric Calibration Sites (CRCS), global multi-sites calibration, inter-calibration with MODIS and invariant targets monitoring. The overall uncertainty in the MERSI top-of-the- atmosphere (TOA) radiance or reflectance is less than 5%.

Comparison of MODIS and VIIRS solar diffuser stability monitor performance

Xiaoxiong Xiong, NASA Goddard Space Flight Ctr. (United States)

Launched in December 1999 and May 2002, Terra and Aqua MODIS have successfully operated for more than 12 and 10 years, respectively: MODIS reflective solar bands (RSBs) are calibrated on-orbit by a solar diffuser (SD). Its on-orbit degradation, or the change in its bi-directional reflectance factor (BRF), is tracked by a solar diffuser stability monitor (SDSM). The SDSM is essentially a ratios radiometer, making alternate observations of direct sunlight through an annular screen (Sun view) and diffusely reflected light from the SD (SD view) during each SDSM calibration event. The SDSM calibration data are collected by 9 filtered detectors, covering wavelengths from 0.41 to 0.94 microns. Due to a design error in MODIS SDSM sub-system (identified post-launch), relatively large ripples have been observed from its Sun view responses. As a result, an alternative approach has been developed by the MODIS calibration team in order to minimize the uncertainty in determining the SD on-orbit degradation. The first VIIRS, on-board the Suomi NPP spacecraft, was successfully launched in October 2011. It carries a MODIS-like SD/SDSM calibration system with an improved design made based on lessons learned from MODIS. The VIIRS SDSM is operated more frequently than MODIS and collects data using 8 individual detectors, which cover a similar wavelength range as MODIS. This paper provides an overview of MODIS and VIIRS SDSM designs, on-orbit operations and calibration strategies, and performance comparisons. Examples of MODIS and VIIRS SDSM detector on-orbit responses and SD on-orbit degradations are illustrated. Also presented in this paper are lessons learned and potential improvements for future SDSM design and operation.

Preliminary analysis of ATMS pitch maneuver data and implications for earth scene simulations

Hu Yang, Univ. of Maryland, College Park (United States) and
National Satellite Meteorological Ctr. (China); Fuzhong Weng, National Environmental Satellite, Data, and Information Service (United States)

ATMS is a total power radiometer and scans in a cross-track manner within ±52.77° with respect to the nadir direction. It has a total of 22 channels with the first 16 channels primarily for temperature soundings from the surface to about 1 kPa (~45 km) and the remaining channels for humidity soundings in the troposphere from the surface to about 200 kPa (~15 km). There are two receiving antennas: one serving channels 1-15 below 60 GHz, and the other for channels above 60 GHz.

The reflector of ATMS is not only collect radiation from main beam, but also collect radiation from side lobe. And since the receiver is not designed purely linear polarized, the cross polarization also need to be taken into account. The magnitudes of side lobe and cross polarization are frequency and antenna size dependent, and can be determined through antenna pattern measurement at ground. In addition, for ATMS observations, reflection and emission from satellite platform through near-field antenna side lobe may also not be ignored.

Bias analysis results for brightness temperature measurements reveals that, there is consistent feature of angular and polarization dependent bias existed for both space scan (through pitch up maneuver) and earth scan. In this paper, based on the antenna pattern measurements and pitch-up maneuver cold space scan brightness temperature measurements, a model was established to explain the angular dependence feature of ATMS measurement bias. By apply the model to earth observation simulation of ATMS, the angular dependent feature of “O-B” bias are significantly removed.

8528-10, Session 3
Lessons from MODIS instrument calibration, operation, and performance (Invited Paper)
Xiaoxiong Xiong, NASA Goddard Space Flight Ctr. (United States); William Barnes, Univ. of Maryland, Baltimore County (United States); James J. Butler, NASA Goddard Space Flight Ctr. (United States)

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument for the NASA’s Earth Observing System (EOS), currently operated on-board the Terra and Aqua spacecrafts. MODIS observations, made in 36 spectral bands with wavelengths ranging from 0.4 to 14.5 microns, have produced an unprecedented amount of data products for a broad range of earth remote sensing applications and made significant contributions to the worldwide science and user communities. With design improvements made over its heritage sensors, MODIS was built with a set of onboard calibrators (OBCs) including a solar diffuser (SD), a solar diffuser stability monitor (SDSM), a blackbody (BB), and a spectroradiometric calibration assembly (SRCA). This paper provides an overview of MODIS instrument calibration, operation, and performance. It focuses on issues identified and lessons learned from both Terra and Aqua MODIS mission operations at different phases and on-orbit calibration and characterization activities. As expected, MODIS experience and lessons have provided and will continue to provide valuable information for other earth-observing missions and sensors. Also illustrated in this paper are examples of MODIS instrument and OBC performance and lessons that have benefitted the Visible/Infrared Imager Radiometer Suite (VIIRS) on-board newly launched Suomi NPP spacecraft.

8528-11, Session 3
The Ocean and Land Colour Imager (OLCI) for the Sentinel 3 GMES Mission: status and first test results
Jens Nieke, Franck Borde, Constantin Mavrocordatos, Bruno Berruti, European Space Research and Technology Ctr. (Netherlands)

Ocean colour sensors are designed to retrieve the spectral distribution of upwelling radiance just above the sea surface (the water-leaving radiance) that is then used to estimate a number of geophysical parameters through the application of specific bio-optical algorithms. Atmospheric correction for ocean colour data is challenging (IOCCG, 2010) as only about 4% of the radiation measured by a satellite instrument originates from the water surface and sensors require high signal to noise ratio (SNR), particularly for the ‘blue’ bands (~400 nm). Ocean colour instrument design must therefore incorporate extremely sensitive and stable radiometry, dedicated on-board calibration and a large number of spectral channels. The Ocean & Land Colour Imager (OLCI) is a high accuracy visible spectral imager selected as optical payload for the Sentinel 3 component of the GMES mission, to provide climatological data continuity with the previous ESA Envisat missions. OLCI is based on the very successful opto-mechanical and imaging design of MERIS. The instrument is a quasi-autonomous, self contained, visible pushbroom imaging spectrometer and incorporates the following significant improvements when compared to MERIS:

- An increase in the number of spectral bands (from 15 to 21),
- Improved SNR and a 14-bit analogue to digital converter,
- Improved long-term radiometric stability,
- Mitigation of sun-glint contamination by tilting cameras in westerly direction,
- Complete coverage over both land and ocean at 300 m Full-Resolution (FR),
- Improved instrument characterization including stray light, camera overlap, and calibration diffusers,
- Improved coverage of the global ocean in < 4 days, the land in <3 days with 1 satellite (ignoring the effect of clouds) compared to MERIS (effectively ~15 days),
- Improved data delivery timeliness of 3 hours for L1b and L2 products,
- 100% overlap with SLSTR instrument swath and simultaneous acquisitions facilitating the use of OLCI and SLSTR in synergy.

The paper highlights the technical and programmatic challenges of the project, first results from the EM test activities and a projected flight model performance summary.

8528-12, Session 3
NPP VIIRS on-orbit performance, data quality, and new applications
Changyong Cao, National Oceanic and Atmospheric Administration (United States); Xiaoxiong Xiong, NASA Goddard Space Flight Ctr. (United States); Slawomir Bionski, Quanhua Liu, Univ. of Maryland, College Park (United States); Fuzhong Weng, National Environmental Satellite, Data, and Information Service (United States); Bruce Guenther, National Oceanic and Atmospheric Administration (United States)

The Visible/Infrared Imager Radiometer Suite (VIIRS) is one of the key instruments on the recently launched NPP and future JPSS missions, succeeding the legacy NOAA/AVHRR, EOS/MODIS, SeaWIFS, and DMSP/OLS as the new generation of operational imaging radiometer. With 22 spectral bands covering wavelengths from 0.41 to 12.5 μm, VIIRS provides data for the production of 21 Environmental Data Records (EDRs) with its calibrated and geocoded Sensor Data Records (SDRs). This paper provides an overview of NPP VIIRS postlaunch instrument performance, onboard and vicarious calibration/validation, and as unique capabilities and potential new applications. Since launch, the VIIRS SDR postlaunch cal/val has been progressing well. Following a series of spacecraft and sensor activation and checkouts, the first VIIRS image was acquired on November 21, 2011, and all 22 bands are producing early images by January 20, 2012. The data maturity has reached beta status in early spring of 2012. Major challenges thus far include the unexpected fast degradation in some NIR channels, and the unprecedented data volume and complexity of the ground processing system. Our goal is to ensure the radiometric, spectral, and geospatial accuracy, and establish consistency with past and future sensors to support the weather, climate, ocean, and other environmental applications.
8528-13, Session 3

CERES flight model 5 on NPP: post-launch performance and initial SDR validation results
Kory J. Priestley, NASA Langley Research Ctr. (United States); Lou Smith, Susan Thomas, Science Systems and Applications, Inc. (United States)

In order to understand our climate, it is necessary to understand the energy flows which govern the movements and the temperatures of the atmosphere and oceans. The solar radiation absorbed by the Earth and its emission as outgoing longwave radiation (OLR) are the heat source and heat sink for this heat engine. The Clouds and Earth Radiant Energy System (CERES) sensors aboard the Terra and Aqua spacecraft have provided the first CERES observed decadal Earth Radiation Climate Data Record (CDR). To assure continuity of this CDR, the CERES FM-5 sensor is currently flying on the NPP spacecraft, launched in October 2011.

The FM-5 sensor was built as part of NASA's EOS program in the late 1990's, originally completing pre-launch calibration in 1999. In 2006, the sensor completed abbreviated radiometric characterization tests to verify stability of performance. In 2008, the sensor was assigned to the NPP mission, removed from storage, prepared for integration on the NPP spacecraft, and subjected to the full pre-launch radiometric characterization campaign.

The Early Orbit Validation & Calibration campaign commenced once NPP reached the operational orbit. This campaign exercised all modes of the sensor, characterized scan angle dependent offsets, observed onboard calibration sources to establish traceability to the pre-launch radiometric scale, and initiated intercalibration opportunities with other CERES sensors operating on NASA's Terra and Aqua missions. Approximately 75 days after launch, the main contamination covers were opened, and nominal science data collection commenced. The current effort summarizes the results of the Launch and Early-orbit checkout of the FM-5 sensor.

8528-14, Session 3

CRISS SDR calibration and validation status and NOAA-STAR related activities
Denis Tremblay, Science Data Processing Inc. (United States); Yong Han, National Oceanic and Atmospheric Administration (United States); Yong Chen, Cooperative Institute for Research in the Atmosphere (United States); Xin Jin, IMSS (United States); Likun Wang, Earth Science Interdisciplinary Center (ESSIC), University of Maryland (United States); Quanhua Liu, Earth System Science Interdisciplinary Center (ESSIC), University of Maryland (United States)

The Crosstrack Infrared Sensor (CRISS) is an Michelson type Fourier Transform Spectrometer that is on-board the SUOMI NPP satellite that was launched into orbit on October 28th 2011. CRISS measures the Top of Atmosphere (TOA) infrared radiance.

The spectral window ranges from 650 to 2550 cm⁻¹ (3.9 to 15.4 μm) divided into 3 spectral bands namely the Long Wavelength (LWIR, 650 to 1095 cm⁻¹), the Medium Wavelength (MWIR, 1210 to 1750 cm⁻¹), and the Short Wavelength (SWIR, 2155 to 2550 cm⁻¹). One Field-Of-Regard (FOR) comprises 9 individuals Field-Of-View (FOV) forming a 3 by 3 grid. At nadir, each FOV has a footprint of 14 Km. One scan comprises 30 crosstrack FORs where the swath (or one scan line) spans 2200 Km. CRISS geographical coverage comprises more than 95% of the Earth surface every day.

The CRISS cooler doors were deployed on January 18th 2012 and the firstlight data were acquired on January 20th 2012. Since the launch of the satellite, CRISS has undergone several calibration and validation phases. The early orbit check-out (EOC) phase was completed in early April 2012. This phase consisted in turning on and optimizing the interferometer. The non-linearity, normalized a2 coefficients, and the instrument line shape (ILS) parameters were computed. Other parameters were also estimated. The BETA maturity level declaration occurred in late April 2012. The next calibration and validation phase is called the intensive calval (ICV). This phase consisted in refining the instrument calibration coefficients and performing a host of validation activities.

The CRISS sensor data record (CRISS SDR) algorithm transforms the raw data record (RDR) into radiometrically and spectrally calibrated spectra. It meets the high quality standard suitable for the usage by the scientific community.

Calibration and validation activities at NOAA Satellite application and research (NOAA-STAR) include:
1. Radiometric validation with respect to the Community Radiative Transfer Model (CRTM).
2. Radiance double difference focusing on FOV comparison.
3. Radiance double difference with IASI.
4. Radiance comparison with AIRS and IASI over the simultaneous nadir overpasses (SNO) locations.
5. Trending and monitoring system that continuously monitors over 55 parameters on a daily basis.
6. Radiance and geolocation validation using the VIIRS products. Calibration and validation of the CRISS SDR is essential because its radiance product is assimilated by the NWP algorithm leading to weather forecasting.

8528-21, Session 3

Ocean altimetry and wind applications of a GNSS nanosatellite constellation
Randall Rose, Southwest Research Institute (United States); Christopher Ruf, Univ. of Michigan (United States); Haruo Seki, Meisei Electric Co., Ltd. (Japan)

Recent developments in electronics and nanosatellite technologies combined with modeling techniques developed over the past 20 years have enabled a new class of altimetry and wind remote sensing capabilities that offer markedly improved performance over existing observatories while opening avenues to new applications. Most existing spaceborne ocean altimetry and wind observatories are in polar low earth orbits; this maximizes global coverage but results in either large gaps at the tropics or long time intervals between geolocation measurement revisits. This combined with their use of radar systems operating in the C and Ku-bands obscures key information about the ocean and the global climate. Using GNSS-based bi-static scatterometry performed by a constellation of 12 nanosatellites in low Earth orbit, ocean altimetry and wind data could be provided with unprecedented temporal resolution and spatial coverage across the full dynamic range of ocean wind speeds in all precipitating conditions - all with a system cost substantially less than existing and planned systems.

This paper contrasts the performance of a GNSS nanosatellite constellation with the existing monolithic remote sensing observatories while identifying synergies of the systems that can be exploited to achieve a more complete understanding of both ocean current and wind phenomena. It describes design requirements, applications, and system implementation for the GNSS nanosatellite constellation while also briefly exploring how the constellation could be applied to critical monitoring applications such as tsunami warning.

8528-15, Session 4

NOAA operational calibration support to NPP/JPSS program (Invited Paper)
Fuzhong Weng, National Environmental Satellite, Data, and Information Service (United States)

Since the launch of the TIROS-N satellite on October 13, 1978, NOAA has been leading for operational calibration of the instruments on board the polar-orbiting satellites. An enterprise approach has been proposed and developed since the launch of NOAA-15 satellite in 1998. Prior to each new NOAA launch, prelaunch TVAC data is analyzed for our independent assessments on key instrument performance. During the intensive calval period, a high quality level-1b radiance data are delivered for applications at NOAA and other centers. The state-of-the-art calibration algorithms are developed, tested and implemented for operation, including lunar calibration and correction models, correction for instrument sudden jumps, simultaneous nadir over-passing (SNO) for cross-calibration, and...
double difference using forward model and deep convective clouds (DCC), etc. These calibration components are now being enhanced for NPP and JPSS missions. The results from the NPP postlaunch calval activities for CrIS, VIIRS, ATMS, and OMPS instruments will be presented at this conference. The impacts of the NPP data on user community such as NWP forecasts will be also discussed.

8528-16, Session 4

Improvements to radiometric consistency between AVHRR, MODIS, and VIIRS in SST bands using MICROS online near-real-time system

Xingming Liang, Alexander Ignatov, Quanhua Liu, Yong Chen, David Groff, National Oceanic and Atmospheric Administration (United States); Xiaoyong Xiong, NASA Goddard Space Flight Ctr. (United States); Changyong Cao, National Oceanic and Atmospheric Administration (United States); Evia Borbas, Univ. of Wisconsin-Madison (United States)

NOAA STAR's Monitoring of IR Clear-Sky Radiance over Oceans for SST (MICROS) was extended in January 2012 to monitor model (CRTM) minus observation, or M-O biases in clear-sky ocean brightness temperatures (BT) in AVHRR-like bands 3.7, 11, and 12m of Terra/Aqua MODIS and NPP VIIRS. In addition to several AVHRRs onboard NOAA-16, -18, -19 and Metop-A monitored since July 2008. The VIIRS M-O biases have been "in-family" with AVHRRs, and the consistency further improved after VIIRS IR calibration was fine-tuned on 7 March 2012. However, MODIS BTs in 11 and 12µm have been biased warm by +0.6 and +0.3K, respectively, relative to AVHRR/VIIRS. No such biases were previously observed when comparing MODIS with AIRS and IASI spectral radiances. Analyses show that these anomalous MODIS biases are due to the use of suboptimal transmittance coefficients for MODIS in CRTM v2.02 currently used in MICROS. With the newest transmittance coefficients updated by the CRTM and University of Wisconsin Teams, the long-wave MODIS BTs have been brought back in family. Meanwhile, the cross-platform inconsistency between Terra and Aqua in Ch20 (3.9µm) of ~0.3K still remains, likely due to calibration uncertainties in MODIS collection 5 L1b product.

This presentation discusses the validation of sensor BTs using the MICROS and the joint effort on identifying and resolving observed differences by the SST Sensor Calibration and CRTM Teams.

8528-17, Session 4

Inter-comparison of NPP/CrIS radiances with VIIRS, AIRS, and IASI: a post-launch calibration assessment

Likun Wang, Univ. of Maryland, College Park (United States); Yong Han, NOAA/NESDIS/STAR (United States); Denis Tremblay, Science Data Processing Inc. (United States); Fuzhong Weng, NOAA/NESDIS/STAR (United States); Mitchell D Goldberg, NOAA JPSS Program Office (United States)

The Cross-track Infrared Sounder (CrIS) on the newly-launched Suomi National Polar-orbiting Partnership (Suomi NPP) and future Joint Polar Satellite System (JPSS) is a Fourier transform spectrometer that provides soundings of the atmosphere with 1035 spectral channels, over 3 wavelength ranges: LWIR (9.14 - 15.38 µm); MWIR (5.71 - 8.26 µm); and SWIR (3.92 - 4.64 µm). An accurate spectral and radiometric calibration as well as geolocation is fundamental for CrIS radiance Sensor Data Records (SDRs). In this study, through inter- and intra-satellite calibration efforts, we focus on assessment of NPP/CrIS post-launch radiometric and spectral calibration. The purpose of this study is to use inter-calibration technologies and systems to quantify the CrIS calibration bias and uncertainties of CrIS.

First, we will compare CrIS hyperspectral radiance measurements with the Atmospheric Infrared Sounder (AIRS) on NASA Earth Observing System (EOS) Aqua and Infrared Atmospheric Sounding Interferometer (IASI) on Metop-A and -B to examine spectral and radiometric consistency and difference among three hyperspectral IR sounders. The newly-launched CrIS on Suomi NPP, combined with AIRS and IASI, provide the first-ever inter-calibration opportunity because three hyperspectral IR sounders can observe the Earth and atmosphere at the same spectral regions from different satellites. We will directly compare CrIS with AIRS and IASI at orbital crossing points of satellites occurring at high latitudes, the so-called simultaneous nadir overpasses (SNO). The CrIS, AIRS, and IASI spectra will be processed at the common grids and then the spectral differences will be computed. Secondly, an accurate collocation algorithm has been developed to collocate high spatial resolution measurements from the Visible Infrared Imager Radiometer Suite (VIIRS) within each CrIS Field of View (FOV). We will compare CrIS spectra-averaged radiances with the spatially-averaged and collocated pixels from the VIIRS IR channels. Since CrIS and VIIRS are onboard on the same satellite platform, the intra-satellite comparison will allow examining the radiometric difference between CrIS and VIIRS with scene temperatures, scan angles, and orbits. In addition, given a high spatial resolution of VIIRS channels, the VIIRS-CrIS comparison results can assess geolocation accuracy of CrIS that have relatively large FOVs (14 km at nadir) using high resolution VIIRS pixel (375m or 750m at nadir).

8528-18, Session 4

Using CEOS reference standard targets to assess the on-orbit performance of Resourcesat-2 AWIFS in comparison with Terra MODIS

Amit Angal, Science Systems and Applications, Inc. (United States); A. Senthil Kumar, National Remote Sensing Ctr. (India); Xiaoyong Xiong, NASA Goddard Space Flight Ctr. (United States); A. S. Kiran Kumar, Space Applications Ctr. (India); V. K. Dadhwal, Indian Institute of Remote Sensing (India); Taeyoung Jason Choi, Sigma Space Corp. (United States)

The Resourcesat-2 (RS2), launched on April 20, 2011 is a follow-on mission to the successfully operational Resourcesat-1 (RS1). Similar to the RS1, RS2 carries 3 multispectral imagers in its platform: the Advanced Wide-Field Sensor (AWIFS), the Linear Imaging Self-Scanner (LISS 3) and the high-resolution multi-spectral scanner LISS-4. This study focuses on assessment of the radiometric calibration stability of RS2 AWIFS sensor by comparing near-simultaneous measurements of Terra MODIS acquired over CEOS reference standard targets. The AWIFS sensor operates four distinct spectral bands: B2 (0.52-0.69 µm); B3 (0.63-0.69 µm); B4 (0.77-0.86 µm) and B5 (1.55-1.7 µm) with a spatial resolution of 56 m. Only those bands of the Terra MODIS spectrally matching to AWIFS bands are compared after basic corrections for variations due to the sun and satellite angles with reference to scene center and the atmospheric transmittance on the given day of acquisition. Synchronous acquisitions of these sensors over the desert regions in Libya, Algeria and Egypt at CEOS recommended geographic coordinates were acquired and processed to compare the Top-of-atmosphere (TOA) reflectance from both sensors. Preliminary results and future efforts are also discussed in this paper.

8528-19, Session 5

Sensitivity analysis of scene dependence of the convolution correction for inter-sensor comparison between multispectral and hyperspectral sensors

Yong Xie, George Mason Univ. (United States)

Accurate radiometric calibration of satellite remote sensor is the prerequisite of science data products and their applications. Besides using the on-orbit calibrators, inter-sensor comparison is one of the best alternative approaches for sensor radiometric calibration, which could transfer the higher radiometric standard from one sensor to another. Among different methodologies, comparing multi-spectral sensor and hyper-spectral sensor is a very popularly used approach. The algorithm is simulating the multi-spectral measurements with hyper-spectral measurements by convoluting the hyper-spectral response with the spectral response function of multi-spectral sensor. During the spectral convolution, due to the spectral response function...
discontinuity of hyper-spectral sensor, an item called convolution correction is applied for compensating the impact caused by spectral discontinuity. In current stage, the convolution correction generally is calculated with MORTRAN at several typical conditions, leading to existence of uncertainties. Since the AIRS and MODIS are both aboard the Aqua spacecraft, inserting the retrieved AIRS real-time atmosphere product into MORTRAN could increase the accuracy of the simulation. With observations made over different scenes, the dependence of the convolution correction upon the real-time atmosphere condition could be obtained, which could then be used to explain some other effects more accurately, such as how much is the center wavelength shift for the thermal emissive bands.

8528-20, Session 5
Earthshine ray tracing simulation with 3D lunar BRDF model for Earth albedo observation
Jinhee Yu, Sug-whan Kim, Yongse Univ. (Korea, Republic of)
No abstract available

8528-23, Session 5
CALIBRATION OF LOW GAIN RADIANCE AT VIIRS EMISSIVE BAND (M13) and VIIRS IMAGE ABOUT MOON TEMPERATURE
Quanhua Liu, National Oceanic and Atmospheric Administration (United States); Vincent Chiang, Sigma Space Corp. (United States); Changyong Cao, National Oceanic and Atmospheric Administration (United States); Xiaoxiong Xiong, NASA Goddard Space Flight Ctr. (United States); Xi Shao, Slawek Blonski, Univ. of Maryland, College Park (United States); Fuzhong Weng, National Environmental Satellite, Data, and Information Service (United States)
Early assessment of the VIIRS thermal emissive bands (TEBs) show that all VIIRS TEBs except M13 are stable and exceed the specifications. M13 is a dual gain band, and is used for determining the surface temperature at low radiance (high gain) and fire detection at high radiance (low gain). At a low gain stage, the onboard blackbody temperature at an operational temperature of 292 Kelvin is far below the lowest temperature at the low gain, which prevents from any attempt to radiometric calibration. This study found that the VIIRS calibration data during the blackbody temperature warm up and cool down (WUCD) and the VIIRS observations to Moon may be useful for the assessment of the VIIRS M13 band radiometric calibration. During the WUCD experiment in February 2012, the blackbody temperature was cooled down to 267 K and warmed up to 315 K. The contrast at the low gain for M13 band between blackbody and space views may be useful, although the highest blackbody temperature is still below the low boundary for the low gain. Moon surface temperature can be as hot as 400 Kelvin, high enough for M13 band radiometric calibration at a low gain. The advantages using the observation data of Moon are that it is very stable and there is no gaseous absorption. However, Moon surface emissivity for infrared spectrum needs to be known and will be discussed. There are some other sources such gas flares that may also be used to estimate the radiometric accuracy at low gain.

8528-64, Session 5
MODIS RSB calibration improvements in Collection 6
Junqiang Sun, Sigma Space Corp. (United States); Amit Angal, Science Systems and Applications, Inc. (United States); Xiaoxiong Xiong, NASA Goddard Space Flight Ctr. (United States)
Since launch, Terra and Aqua MODIS have performed more than 12 and 10 years of scientific measurements of the Earth’s surface. MODIS has 36 spectral bands, among which 20 are Reflective Solar Bands (RSB), covering a spectral range from 0.41 μm to 2.1 μm. MODIS was developed with stringent requirements for calibration and uncertainty and hence is equipped with a set of on-board calibration sensors, which facilitate a constant monitoring and update of its on-orbit calibration coefficients. The RSB are calibrated on-orbit using a Solar Diffuser (SD) and a Solar Diffuser Stability Monitor (SDSM), with help from the lunar observations via a Space View (SV) port and an onboard Spectroradiometric Calibration Assembly (SRC). The algorithms to accurately characterize the sensor’s gain change and the on-orbit change in the response versus scan-angle (RVS) have been applied to improve the quality of the Earth-view measurements. Various improvements to the calibration algorithms have been incorporated since launch and the following paper will discuss the calibration algorithms and enhancements developed for MODIS Collection 6 (C6) processing. In addition, to the measurements from the on-board calibrators, the pseudo-invariant desert targets are also used to track the on-orbit response change for selective RSB. Discussions of the on-orbit calibration uncertainty and the Level 1B (L1B) Uncertainty index (UI) product are also included. A comprehensive assessment of the impact on the L1B product in comparison to Collection 5 (C5) is also discussed.

8528-25, Session 6
PHazeRS: a polar haze cubesat concept
Jose V. Martins, Earth Resources Technology, Inc. (United States); Mark Schoeberl, NASA Goddard Space Flight Ctr. (United States)
The Polar Haze Research Satellite (PHazeRS) is a cubesat concept that would make solar aureole measurements to determine the size, composition and density of polar haze aerosols. Polar haze has been linked to rapid warming of the Arctic, and, aside from a few aircraft missions, little is known about the 3D distribution of the haze. PHazeRS is a sun-point occultation system similar to the very successful SAGE systems. However, PHazeRS, unlike SAGE, deploys a calibrated 1.e-4 ND blocker upon release that attenuates the direct solar beam. Photographs of the sun and the solar aureole setting across the limb provide information from a large number of scattering angles providing extensive information on the aerosol composition. Like SAGE, PHazeRS is self-calibrating. In polar orbit, PHazeRS would provide extensive mapping of Arctic haze shortly after it begins to develop in Spring and throughout spring, summer and fall.

8528-27, Session 6
A new approach for spectroradiometric calibration consistency on the ground and in space
Donald F. Heath, Heath Earth (United States); Georgi Georgiev, Sigma Space Corp. (United States) and NASA Goddard Space Flight Ctr. (United States)
In the solar reflective wavelength region the spectral albedo calibrations of space instruments are tied often to either the spectral albedo of a solar diffuser or the Moon. The Space-based Calibration Transfer Spectroradiometer (SCAT) sensor uses a simple, invariant optical configuration and dedicated narrow band spectral channel modules to provide very accurate, polarization-insensitive, stable spectral measurements of earth albedo and lunar disk albedo. Optical degradation effects on calibration stability are eliminated through use of a common optical system for observations of the Sun, Earth, and Moon. The measurements from space would be traceable to SI units through preflight calibrations of radiance and irradiance at NIST’s SIRCUS facility and the invariant optical system used in the sensor. Simultaneous measurements are made in multiple spectral channels covering the solar reflective wavelength range of 300 nm to 2.4 microns. A mini spectrgraph can be used to provide interpolation of the spectral albedo channels. The large dynamic range of signals is handled by use of photodiodes which are highly-linear detectors, stable discrete electronic components, and a non imaging optical configuration. By observing the Sun on every orbit, the most stringent stability requirements of the system are limited to short time periods. The invariant optical system for both radiance and irradiance measurements also give excellent transfer to-orbit SI traceability. A Mie scattering diffuser (MSD) which is fabricated from opaque fused
silica is used to transfer a NIST derived spectral albedo calibration to SCATS, and other space instruments in the solar reflective wavelength region.

8528-28, Session 7
An overview of space applications for environment initiatives
Shinichi Sobue, Toru Fukuda, Tomoyuki Nukui, Kei Oyoshi, Japan Aerospace Exploration Agency (Japan)

Recently, climate change and human activities accelerate hazards, such as deforestation, land slides, draughts, floods in Asian-Pacific countries are increased. To mitigate the hazards due to climate change and human activities, environmental monitoring has become important. Environment change monitoring by using space based technology is particularly important. Asian Pacific regional forum (APRSAF) agreed to host SAFE (Space Applications For Environment) initiatives. SAFE is a voluntary-based initiative. It aims to encourage the environmental monitoring in long-term to grasp the environmental changes that may be useful to bring in risk reduction and adaptation programs for disasters risk related activities to other climate change associated problems using space applications, especially satellite remote sensing technology. Some of the changing environment parameters in water resources, river water level, land cover, deforestation, agriculture production, and ecosystem could provide through satellite remote sensing.

SAFE considers continuous data provision with sensor data that could provide environment sensitive information with varying spectral and spatial resolution for better understanding the status of the environment and its changes. SAFE is a more robust approach for long-term monitoring of our natural environment with satellite remote sensing to evaluate current status, understand the changes, monitor the nature of changes and where possible use as base information for risk management and adaptation. Further, the end users of SAFE are the agencies and experts work on various agencies that are responsible for the environment. These agencies have their own mandate, functionalities and responsibilities to sustainable management of the environment.

8528-29, Session 7
Applications of an automatic change detection for disaster monitoring by the knowledge-based framework
Takeo Tadono, Japan Aerospace Exploration Agency (Japan); Shutaroh Hashimoto, Masahiko Onosato, Hokkaido Univ. (Japan); Masahiro Hori, Japan Aerospace Exploration Agency (Japan)

Change detection is a fundamental approach in utilization of satellite remote sensing especially for multi-temporal analysis that involves extracting damaged areas by a natural disaster. Recently, the amount of data obtained by Earth observation satellites has increased significantly owing to the increasing number and types of observing sensors, the enhancement of their spatial resolution, and improvements in their data processing systems. In applications for disaster monitoring, in particular, fast and accurate analysis of broad geographical areas is required to facilitate efficient rescue efforts. It is expected that robust automatic image interpretation is necessary. Several algorithms have been proposed in the field of automatic change detection in past, however they are still lack of robustness for multi purposes, an instrument independency, and accuracy better than a manual interpretation.

We are trying to develop a framework for automatic image interpretation using ontology-based knowledge representation. This framework permits the description, accumulation, and use of knowledge drawn from image interpretation. We described an example of a ‘remote sensing ontology’, which is a heavyweight ontology and includes definitions of concepts that human beings are able to identify within satellite imagery. Local relationships among certain concepts defined in the ontology are described as knowledge modules and are collected in the knowledge base. Our knowledge representation uses a Bayesian network as a tool to describe various types of knowledge in a uniform manner. Knowledge modules are synthesized and used for target-specified inference. The results applied to some types of disasters by the proposed framework without modification or tuning are shown in this paper.

8528-30, Session 7
The assimilation of satellite microwave observation in JMA’s meso-scale model
Masahiro Kazumori, Japan Meteorological Agency (Japan)

Accurate numerical weather prediction is one of the essential information for natural disaster prevention. Japan Meteorological Agency (JMA) has been implementing a Meso-scale model (MSM). The target of the MSM is to provide guidance for issuing warnings or making very short-range forecasts of precipitation to cover Japan and its surrounding areas. In order to produce accurate precipitation forecasting, realistic moisture fields as initial conditions are necessary. The initial fields are produced in analysis with a four dimensional variational data assimilation method. The initial fields are updated eight times per day to capture rapid change of mesoscale weather phenomena in the forecasts.

Because Japan is a country surrounded by ocean, moisture information over the ocean is a key for the accurate humidity analysis and the precipitation forecasting. Observations of microwave radiometers in space contain the moisture information over the ocean. The data are available in wide coverage under all weather conditions. Although the ocean is data sparse area, the satellite microwave radiometer’s data can fill the gaps in spatially and temporally. The data plays important role in the humidity analysis.

In the analysis, microwave brightness temperature and retrieved precipitation from various microwave radiometers are assimilated. Generally, the assimilation of these data brings improvement of the humidity analysis and the precipitation forecasting. Use of multiple satellite data is necessary for the frequent updates of the initial field. Recent activities toward the introduction of the Advanced Microwave Scanning Radiometer-2 data in the analysis will be presented in the conference.

8528-22, Session PSWed
An overview of MODIS RSB calibration and look-up-table delivery process
Amit Angal, Science Systems and Applications, Inc. (United States); Hongda Chen, Taeyoung Jason Choi, Xu Geng, Junqiang Sun, Brian Wenny, Sigma Space Corp. (United States); Xiaoxiong Xiong, NASA Goddard Space Flight Ctr. (United States)

The Moderate Resolution Imaging Spectroradiometer (MODIS) is an Earth-observing sensor currently operational on the Earth Observing System (EOS) Terra and Aqua satellites. Each MODIS instrument has 36 spectral bands, with data acquired using 490 detectors in the reflective solar and thermal emissive spectrum. The 20 reflective solar bands (RSB), covering a wavelength range from 0.4 to 2.2μm, are calibrated on-orbit using a solar diffuser (SD), solar diffuser stability monitor (SDSM), and regularly scheduled lunar measurements. The instrument gain (m1) derived from SD measurements and the response versus scan-angle (RVS) derived using the SD and lunar measurements are the primary look-up-tables (LUT) that are updated on a regular basis. The short wavelength bands of both MODIS instruments have experienced a gain change of up to 50% as observed from the SD calibration. Given the longevity of both MODIS sensors, the detectors have aged, and sensor’s radiometric characteristics have changed since launch. A strong dependence of the RVS on mirror side, detector, wavelength and time is also observed in these visible (VIS) channels. The MODIS Characterization Support Team (MCST) is responsible for deriving and updating the on-orbit calibration coefficients. An accurate and timely update of the LUT is vital for maintaining the quality of the calibrated Level 1B (L1B) product. The following paper provides an overview of the MODIS RSB calibration along with the major procedures used to regularly update the LUT. In addition, the various lessons learned and future improvements are also discussed.
Assessments of FY-3A microwave humidity sounder (MWHS) measurements using NOAA-18 microwave humidity sounder (MHS)

Li Guan, Nanjing Univ. of Information Science & Technology (China); Xiao Lei Zou, The Florida State Univ. (United States)

The measurements from FY-3 MicroWave Humidity Sounder (MWHS) are compared with the data from NOAA-18 Microwave Humidity Sounder (MHS) which has higher spatial and frequency resolution. A quality control (QC) procedure is applied to allow the comparison be conducted separately for outliers and non-outliers. The QC algorithm includes a gross error check, instrument noise spikes through noise equivalent differential temperature (ΔT), and an O-A bi-weighting check, where O represents satellite observations, and A is model-simulated brightness temperature by Radiative Transfer for TIROS-N Operational Vertical Sounder (RTTOV) based on the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) final gridded analyses and forecast datasets. It is found that: (i) the global mean bias and standard deviation of O-A from MWHS brightness temperatures are comparable in magnitudes to those of MHS data even though NOAA-18 MHS radiances were assimilated in NCEP GFS analyses fields; (ii) positive O-A outliers prevail in channel 3 for both satellite instruments; and (iii) biases of channels 4 and 5 are predominantly negative over land for both FY-3A and NOAA-18 satellites. A series of sensitivity experiments are carried out to demonstrate that the large positive O-A biases could be due to the errors in the atmospheric water vapor profiles from the analysis fields being too wet, and that the negative biases over land arise mostly from errors in surface emissivity, but smooth model terrain also contributes negative biases over land.

Preliminary analysis of ZY-3 satellite imagery geolocation accuracy

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ZY-3 satellite was launched at 9th January 2012, which is the first high resolution civil stereo satellite of China, mainly used in stereo mapping, resource investigation, disaster prevention and reduction. The satellite is equipped with forward-backward stereo cameras, one nadir camera, and one multispectral camera, with resolution up to 3.6m, 3.6m, 2.1m, 5.8m respectively, and the width is about 52 km. In this paper, ZY-3 imaging geometry method is discussed based on rational function model, collinearity equation of line array image, 8-parameter 3D affine model and 2D polynomial with terrain correction, etc, respectively, and the positioning accuracy of the above imaging models are researched without ground control points (GCP) and with limited GCP individually. Meanwhile, related experiments are carried out using data in Yan-an Shaanxi of China during the period of commissioning (7th February), in which 91 precise GCPs with height difference around 400 m are used to test the accuracy of images of Forward, Backward, Nadir and Multispectral cameras. In the result, it shows that the geolocation accuracy of image by rational function model could be within 50 m in plane (CE90) without any GCP, while with the support of a few GCPs, and perform least square adjustment to the above 4 kinds of images using 4 different models respectively, the RMS georeferencing accuracy reaches sub-pixel level in all cases.

The correction of TMI brightness temperature due to TRMM boost

Yu Wang, Yunfei Fu, Wei Tao, Qi Liu, Univ. of Science and Technology of China (China)

The satellite orbit of the Tropical Rainfall Measuring Mission (TRMM) was boosted from 350km to 402km in August 2001. This caused that the incidence angle of the TRMM Microwave Imager (TMI) was changed, in turn the surface emissivity and the observed brightness temperature (Tb) changed. A result, atmospheric parameters retrieved from TMI Tb have shown a spurious jump from the pre- to the post-boost periods. In order to insure measurements consistency for these two periods to establish long-time dependable observations, in turn retrievals datasets for climate research, in this study the changes in Tbs from the pre-boost period to post-boost period over the ocean are investigated, and corresponding mechanism is analyzed, as well as a correction algorithm to adjust the post-boost TMI measurements consistent to the pre-boost measurements is presented. Results show Tbs on various polarized channels for the lower frequencies have the largest increase with 0.8-1.6K, while those in high frequency are much less pronounced, which are mainly caused from surface emissivities changing with the incidence angle. By a linear correction, pre- and post-boost Tbs become continuous, especially the spurious Tb jump is removed on salient channels for low frequency is removed. This study would be helpful to establish reliable and continuous observations for climate study in the future.

Current status of global rainfall map using satellite-borne microwave radiometers by the GSMaP project

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As a proto-type for Japanese Global Precipitation Measurement (GPM) mission products, Japan Aerospace Exploration Agency (JAXA) has developed and operated near-real-time data processing system with passive microwave radiometer (PMW) data (i.e., TRMM TMI, Aqua AMSR-E, and DMSP SSM/I) and GEOS IR data and distributed rainfall products via the Internet (http://sharaku.eorc.jaxa.jp/GSMaP/). Horizontal resolution is 0.1-degree latitude/longitude grid and temporal resolution is 1 hour. The latency of our near-real-time product (GSMaP_NRT) is about four hours after observation. Core algorithms of the system are based on the combined PMW-IR algorithm developed under the Global Satellite Mapping of Precipitation (GSMaP) project (Okamoto et al. 2005, Kubota et al. 2007, Aonashi et al. 2009, Ushio et al. 2009, Shige et al. 2009, Kachi et al. 2011). In order to improve sampling of observation of rainfall, the products from passive microwave imagery/sounder (i.e., DMSP SSMIS) since 11 Jun. 2010 and passive microwave sounder data from NOAA-19 and MetOp-A since 1 Aug. 2011 is introduced into the near-real-time system. Currently, the near-real-time system is operated with 7 PMW data and GEO IR data. In addition, we completed re-processing (re-collection and more elaborated algorithms) with the period during 2000-2010 on March 2012. The GSMaP algorithms have been improved using precipitation information from TRMM Ku-band Precipitation Radar (PR). Utilization of Dual-frequency Precipitation Radar onboard GPM Core Observatory launched in 2014 will be the next cornerstone for the GSMaP project.

Design and analysis of the multispectral remote sensing imager

Shenq-Tsong Chang, Instrument Technology Research Ctr. (Taiwan); Cheng-En Ho, Mei-Yi Yang, Heng-Chuan Hung, National Space Organization (Taiwan); Ting-Ming Huang, Instrument Technology Research Ctr. (Taiwan); Chia-Ray Chen, National Space Organization (Taiwan)

This article describes the optical and structural design, and the results of tolerance, finite-element and thermal analysis of Remote sensing imager (RSI) of Formosat-5. Formosat-5 is the first self-reliant remote sensing satellite of Taiwan. RSI is the primary payload on it. RSI is a multispectral imager which contains one panchromatic band with 2-meter ground sampling distance (GSD) and four multispectral bands with 4 m GSD. Optical design of the RSI is performed to...
meet the requirements. Cassegrain type of optical design has been selected. Several designs have been studied to reduce the alignment sensitivity and the effect of the orbital deformation according to the size restriction. The truss configuration of structural design has been selected, and M2 support ring is design to support the secondary mirror. Following tolerance, finite-element, and thermal analyses are performed. The tolerance of radius of curvature is one thousandth of radius. The first mode of the telescope is 81.3 Hz when the total mass is 85.7 kg. First mode of vibration occurs along the lateral direction that is perpendicular to the launch axis. TRASYS and SINDA model of RSI have been established for thermal analysis. Hot and cold cases have been studied. The result shows that 39.4W of heater power is required in cold case.

8528-58, Session PSWed

The extreme ultraviolet imagers (EUVIs): Earth-observing telescopes on International Space Station

Kentarou Uji, Ichiro Yoshikawa, The Univ. of Tokyo (Japan); Kazuo Yoshioaka, Go Murakami, Atsushi Yamazaki, Japan Aerospace Exploration Agency (Japan)

The Extreme Ultraviolet Imagers (EUVIs) will be launched in 2012 as payloads to the Exposed Facility of the Japanese Experiment Module (JEM-EF) on the International Space Station. The EUVIs are parts of the MAP (Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping) mission to observe the Earth’s upper atmosphere, upper mesosphere, ionosphere, thermosphere and plasmasphere. The other part of MAP is a visible and near-infrared spectral imager (VISI).

In this mission, we install two independent and identical telescopes. One telescope detects the terrestrial EUV emission from O II (at the wavelength of 83.4 nm), and the other one detects He II (30.4nm).

The optical instruments consist of multilayered coated mirrors which are optimized for 30.4nm, metallic thin filters and 5-stage microchannel plates to pick up photon events efficiently.

In our presentation, we report the mission overview, the instruments and the result of ground calibrations.

8528-59, Session PSWed

GOES-R AWG product processing system framework

Shanna Sampson, Walter Wolf, Aiwu Li, Tianyu Yu, National Oceanic and Atmospheric Administration (United States); Raymond K. Garcia, Graeme Martin, Univ. of Wisconsin-Madison (United States); Xingpin Liu, National Oceanic and Atmospheric Administration (United States); William Straka III, Univ. of Wisconsin-Madison (United States); Meizhu Fan, National Oceanic and Atmospheric Administration (United States); Eva Schiffer, Univ. of Wisconsin-Madison (United States); Mitchell D. Goldberg, National Oceanic and Atmospheric Administration (United States)

NOAA/NESDIS/STAR has designed, developed, and implemented the GOES-R Algorithm Working Group (AWG) Product Processing System Framework. The Framework enabled the development and testing of the Level 2 Advance Baseline Imager (ABI) and the GOES-R Lightning Mapper (GLM) products within a single system. Fifty-six GOES-R ABI algorithms and one GLM algorithm have been integrated and run within the framework with product precedence. The Framework has been modified to be a plug-and-play system with the scientific algorithms. To enable the plug-and-play capabilities, the fifty-seven ABI and GLM algorithms were adjusted such that any data required by the algorithm is brought into the algorithm through function calls. These modifications allowed an algorithm to be developed either within the Framework or within the scientist’s offline research system. This approach provided both the algorithm developers and algorithm integrators the ability to work on the same software since the algorithm may be “dropped” into both systems resulting in simple algorithm rollbacks. The design features and the current status of the framework will be discussed.

8528-60, Session PSWed

Agricultural monitoring for food security with high-temporal resolution imagery

Kei Oyoshi, Shinichi Sobue, Japan Aerospace Exploration Agency (Japan)

Food security is a critical issue for the international community. In June 2011, the meeting of G20 agriculture ministers was held to improve food security and they agreed on an Action Plan on food price volatility and agriculture. This plan includes the utilization of remote sensing tool to improve crop production projections and weather forecasting. Hence, satellite remote sensing is expected to contribute national, regional and global food security through the systematic and efficient collection of food security related information such as agro-meteorological condition, crop growth or yield estimation. This information will be utilized to take mitigation strategies as means to manage food shortages or trading, and ensure food security. However, land surface conditions of croplands are highly time variant depends on the agricultural land management by farmers or crop response to meteorological condition. In order to fulfill the requirements to apply Earth observation data to food security, it is necessary to acquire clear data without cloud contaminations once or twice a month. Optical imager and microwave radiometer with high-temporal repeat frequency such as MODIS, AMSR-E, SPOT VEGETATION, AVHRR, and GCOM (GCOM-W AMSR2, GCOM-C SGLI) series are useful for identifying crop calendar, operational evaluation of vegetation vigor and estimation of agro-meteorological conditions including precipitation, photosynthetic active radiation, land surface temperature and soil moisture because near-real time observation data are available. In this research, we demonstrate usefulness of the high-temporal resolution sensors through the introduction of crop phenology and agro-meteorological monitoring studies and developed prototype of crop monitoring systems.

8528-61, Session PSWed

Monitoring landscape change in Kathmandu metropolitan region using multi-temporal satellite imagery

Rajesh Bahadur Thapa, Japan Aerospace Exploration Agency (Japan)

The increasing availability of time series satellite images and improving techniques have allowed mapping and detecting landscape change in densely populated and topographically complex urban areas. This research aims to investigate temporal landscape change in Kathmandu metropolitan region for the last five decades. Incorporating with other ancillary data, the CORONA (1967), Landsat (1978, 1991, and 2000), and ALOS (2010) satellites images were processed applying hybrid image classification method. Twelve land use types were mapped. The ALSO provided multispectral high resolution images from PRISM and AVNIR sensors than the other satellites that revealed specific details of current urban landscape and improved mapping accuracies. Dynamic spatial patterns of urban landscape are observed where the built-up areas gradually increased in the 1970s but had a speedy growth since the 1990s. Prime agricultural landscape in the valley floor has been converted to built-up areas. Forest and shrubs landscapes in rural areas are mostly changed to agricultural uses. Landscape transitions between other land uses are nominal. Trends of fragmentation and heterogeneous landscape development were prominent in the early decades. Expansion of built-up area has progressively become uniform in recent decades. A refill type of development in the city core and adjacent areas has shown a decreasing trend of the neighborhood distances and an increasing trend of physical connectedness between the different land uses. This process indicates a higher probability of homogenous landscape development particularly built area in upcoming decades which may further degrade the urban ecosystem services and cause environmental disaster in the metropolitan region.
On-orbit calibration of TAnSO on gOSAT
Kei Shiomi, Shuji Kawakami, Hiroshi Suto, Akihiko Kuze, Japan Aerospace Exploration Agency (Japan)

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 and obtains normal operation data over 3 years. 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 1.6 microns to detect cloud and aerosol interference in the FTS IFOV with high spatial resolution and wide swath of 1000 km.

The GOSAT is operated successfully and acquired observation data over three years. The calibration accuracies are evaluated in annual trends. Radiometric accuracies 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 geometric accuracies are monitored by the GCPs on reference image and coastline database continuously. Spectral accuracies are monitored by solar Fraunhofer line. This presentation shows the calibration results of TANSO FTS and CAI after 3 years operation.

8528-34, Session 8
GOSAT higher level products and the variation of retrieved XCO₂ and XCH₄
Hiroshi Watanabe, Akira Yuki, Fumie Kawazoe, Sayaka Kanekon, Masatake Ajiro, Tsuneo Matsunaga, Tatsuya Yokota, National Institute for Environmental Studies (Japan)

During the 3.5-year operation of GOSAT (Greenhouse gases Observing Satellite), NIES GOSAT DHF (GOSAT Data Handling Facility of National Institute for Environmental Studies) has been producing some standard products from the data of TANSO-CAI (Cloud and Aerosol Imager) and TANSO-FTS (Fourier Transform Spectrometer). The standard data products of CAI Level 1B/1B+; FTS Level 2 SWIR (column amount of CO2 and CH4), FTS Level 2 TIR (profiles of CO2 and CH4 concentration), CAI Level 2 (cloud flag), FTS Level 3 (global map of XCO₂, XCH4), and CAI Level 3 (global radiation and global reflectance) have been provided to general users. In addition, CAI Level 3 NDVI (Normalized Difference Vegetation Indices) and FTS Level 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 1.6 microns to detect cloud and aerosol interference in the FTS IFOV with high spatial resolution and wide swath of 1000 km.

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Calibration comparison of GOSAT TANSO TIR band using Aqua AIRS and MetOp IASI

Robert O. Kruteson, Henry E. Revercomb, David C. Tobin, P. Jonathan Gero, Univ. of Wisconsin-Madison (United States); Akihiko Kuze, Kei Shiomi, Japan Aerospace Exploration Agency (Japan)

The simultaneous nadir overpasses (SNOs) of GOSAT with NASA Aqua and EUMETSAT MetOp satellites for a two year period have been used to compare the zenith upwelling infrared radiance observations from the TANSO TIR band calibrated spectra with the same measurements from the AIRS and IASI sensors. Previous SNOs studies between AIRS and IASI have shown brightness temperature agreement in the TANSO TIR band with the same measurements to compare the zenith upwelling infrared radiance observations from the AIRS and IASI sensors. Previous SNOs studies between AIRS and IASI have shown brightness temperature agreement in the TANSO TIR band with the same measurements to compare the zenith upwelling infrared radiance observations from the AIRS and IASI sensors.

Characterization and validation of CO2 and CH4 products from GOSAT thermal infrared band

Tomoaiki Tanaka, Kei Shiomi, Shuji Kawakami, Japan Aerospace Exploration Agency (Japan); Naoko Saitoh, Chiba Univ. (Japan); Ryoichi Imasu, The Univ. of Tokyo (Japan); Makoto Inoue, Isamu Morino, Osamu Uchino, National Institute for Environmental Studies (Japan); Colm Sweeney, Pieter Tans, National Oceanic and Atmospheric Administration (United States)

The Thermal and Near Infrared Sensor for Carbon Observation Fourier-Transform Spectrometer (TANSO-FTS) installed on Greenhouse Gases Observing Satellite (GOSAT) measures spectra absorbed by atmospheric minor components including greenhouse gases in infrared wavelength regions. It has three narrow bands (0.76, 1.6, and 2.0 μm) in short-wavelength infrared (SWIR) region and one wide band (5.5-14.3 μm) in thermal infrared (TIR) region.

This paper describes the characterization and validation of the CO2 and CH4 profiles retrieved from the TIR spectra. The retrieved CO2 and CH4 profiles were compared with the aircraft data provided by National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) Global Monitoring Division (GMD) Carbon Cycle Greenhouse Gases group. They have been conducting an aircraft program since 1992 to collect air samples mainly in North America. In most aircraft flights, 12 flask samples are collected on a biweekly-to-monthly basis at different altitudes up to 8000 m.

Each in situ aircraft profile is compared with all profiles retrieved from TIR data within the corresponding 24-h period and ± 2° longitude and latitude, without considering the effect of its averaging kernel. The root mean square and bias errors of the retrieved CO2 and CH4 profiles were evaluated seasonally with respect to the atmospheric pressure in this paper. The comparisons with aircraft data provide significant information for future improvement of the TIR retrieval algorithm.
sensor that will be on board ALOS-3 Satellite in 2015 or later. HSIU is composed of two radiometers; one is a hyperspectral imager that obtains spectral images of 165 bands with the ground sampling distance of 30 meters from the visible to shortwave-infrared region, and the other is a multispectral imager that covers the wide swath of 90 km with the ground sampling distance of 5 meters. The sensor system is the follow-on mission of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) in the visible to shortwave infrared region. Synergetic operation of these instruments acts an important role in the future spatial-spectral data. The tests of an evaluation model of HSIU have been carried out and the critical design review will be accomplished in 2014. Simultaneously in the key components of the flight model are being developed. The results of the test of evaluation model and the development status of flight model are reported in this work.

8528-40, Session 9

PI-SAR-L2 observation of agricultural area damaged by seawater caused by the Great East Japan Earthquake in 2011

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Massive earthquake occurred on the eastern coast of Japan on March 11, 2011. The earthquake of magnitude 9.0 was the biggest ever observed in Japan. The height of the tsunami that followed the earthquake was estimated to be more than 10 m, reaching a few kilometers inland and causing serious damage to humans, buildings and agricultural area along the coastline. Several Pi-SAR-L2 observations were carried out in these tsunami affected area on April 18, 2012, and simultaneous field experiment were performed in agricultural areas damaged by seawater. Complex dielectric constant of the soil surface was measured by open mode probe method with frequency range of 0.5 to 6 GHz. The imaginary part of the dielectric constant for tsunami damaged area show larger value than the one for the non-damaged area. The imaginary part of the dielectric constant at 1 GHz for non-damaged area are less than 5, while those for the salt damage area are often more than 5. These results are compared with the PiSAR-L2 data, and are used to discuss about monitoring of salt damage area by L-band SAR data

8528-41, Session 10

Status of AMSR2 instrument on GCOM-W1

Keiji Imaoka, Takashi Maeda, Misako Kachi, Marehito Kasahara, Norimasa Ita, Keizo Nakagawa, Japan Aerospace Exploration Agency (Japan)

The Global Change Observation Mission (GCOM) consists of two polar orbiting satellite observing systems, GCOM-W (Water) and GCOM-C (Climate), and three generations to achieve global and long-term monitoring of the Earth. GCOM-W1, the first satellite of the GCOM-W series, is scheduled for launch on May 2012. The satellite system is already at the Tanegashima Space Center, from where the satellite will be launched, and the final preparations are underway. The Advanced Microwave Scanning Radiometer-2 (AMSR2), which is a successor of AMSR on the Advanced Earth Observing Satellite-II (ADEOS-II) and AMSR for EOS (AMSR-E) on NASA's Aqua satellite, is a single mission instrument on GCOM-W1. Basic characteristics of AMSR2 is similar to that of AMSR-E to continue the AMSR-E observations, with several enhancements including larger main reflector (2.0 m), additional channels at the C-band frequency band, and improved calibration system. AMSR-E halted its observation on October 4, 2011, due to the increase of antenna rotation torque. Although all the efforts are being made to resume the AMSR-E observation, early initiation of the AMSR2 observation is highly desired. After the completion of the orbit injection into the A-Train constellation, AMSR2 will start rotating and initiate global observation. During the initial calibration and validation phase, brightness temperatures will be evaluated and characterized through methodologies such as the inter-calibration among similar microwave radiometers including the TRMM Microwave Imager (TMI) and WindSat on Coriolis mission. At the conference, the overview of the instrument and the initial results of characterization will be described.

8528-42, Session 10

Products and science from GCOM-W1

Taikan Oki, The Univ. of Tokyo (Japan); Keiji Imaoka, Misako Kachi, Japan Aerospace Exploration Agency (Japan)

The Advanced Microwave Scanning Radiometer-2 (AMSR2) will be launched as a single mission instrument onboard on the first satellite of the Water Series of Global Change Observation Mission (GCOM-W1). AMSR2 is multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands, and a successor of AMSR on the Advanced Earth Observing Satellite-II (ADEOS-II) and AMSR for the Earth Observation System (AMSR-E) on NASA's Aqua satellite. Participation of GCOM-W1 in the A-Train constellation has been coordinated. GCOM-W1 is scheduled to be launched in May 2012, and initial products will be introduced. There are eight geophysical standard products of GCOM-W1 based on AMSR2. They are integrated water vapor, integrated cloud liquid water, sea surface temperature, sea surface wind speed and sea ice concentration over ocean, snow depth and soil moisture content over land, and precipitation over the globe except for high latitudes. Data assimilation system under GCOM mission has not yet been defined, however, offline simulation system on water cycles over global land is under development, using a land surface model driven by atmospheric forcing from satellite observations and assimilated data products. In addition to water balance components such as evapotranspiration, runoff, and soil moisture, river discharge is also calculated. The system is under improvement at EORC for combined use of products from satellite data and Gridded Point Value (GPV) data, which includes objective analysis and forecasts by JMA's operational Global-Scale Model. Such a system will be a basis for real-time data assimilation in the future.

8528-43, Session 10

Overview of GCOM-C/SLGI science

Yoshiaki Honda, Chiba Univ. (Japan)

For monitoring of global environmental change, the Japan Aerospace Exploration Agency (JAXA) has made a new plan of Global Change Observation Mission (GCOM). SLGI (Second Generation GLI) onboard GCOM-C (Climate) satellite, which is one of this mission, provides an optical sensor from Near-UV to TIR. Characteristic specifications of SLGI are as follows; 1) 250m resolutions over land and area along the shore, 2) Two directional polarization observation (red and NIR), and 3) 500m resolutions temperature over land and area along shore. These characteristics are useful in many fields of social benefits. In addition, 51 products will be made by mainly 35 principal investigators. We introduce the overview of GCOM-C/SLGI science.

8528-44, Session 10

Engineering model testing for SLGI IRS especially TIR radiometric data

Tamiki Hosokawa, NEC TOSHIBA Space Systems, Ltd. (Japan)

The Japan Aerospace Exploration Agency (JAXA) has the plan of the Global Change Observation Mission (GCOM) for monitoring global environmental change. Second generation Global Imager (SLGI) is a mission instrument to be installed on the satellite of GCOM Mission Climate (GCOM-C) satellite. SLGI is the optical radiometer observed to the frequent Global, Ocean, Land, Cloud and Ice sphere to help determine the Earth's climate change.

SLGI is a suite of two radiometers called VNR and IRS. The VNR is employing a wide swath (1150km) push-bloom scan with line CCD detector. IRS is employing a conventional cross-track mirror scan system (1400km swath) with cooled infrared detector.

We report the SLGI IRS Engineering Model Testing especially TIR radiometric data.
An overview of the cryosphere products and validation plans for GCOM-C1/SGLI observations

Masahiro Hori, Japan Aerospace Exploration Agency (Japan); Teruo Aoki, Meteorological Research Institute (Japan); Knut Stamnes, Stevens Institute of Technology (United States); Tomonori Tanikawa, Japan Aerospace Exploration Agency (Japan); Wei Li, Nan Chen, Stevens Institute of Technology (United States)

The “Global Change Observation Mission-Climate” (GCOM-C) is a project of Japan Aerospace Exploration Agency (JAXA) for the global and long-term observation of the Earth environment. The GCOM-C is a part of the JAXA’s GCOM mission which consists of two satellite series, GCOM-C and GCOM-W (Water), spanning three generations in order to perform uniform and stable global observations for 13 years. GCOM-C carries a multi-spectral optical radiometer named Second Generation Global Imager (SGLI), which will have special features of wide spectral coverage from 380nm to 12µm, a high spatial resolution of 250m, a field of view exceeding 1000km, two-direction simultaneous observation, and polarization observation. The GCOM-C mission aims to improve our knowledge on the global carbon cycle and radiation budget through high-accuracy observation of global vegetation, ocean color, temperature, cloud, aerosol, and snow and ice. As for the cryosphere products, not only snow cover extent but also snow physical parameters are retrieved from SGLI data such as snow grain sizes at shallow layers, temperature, and mass fraction of impurity mixed in snow layer and so on. These snow physical parameters are important factors that determine spectral albedo and radiation budget at the snow surface. Thus it is essential to monitor those parameters from space in order to better understand snow metamorphosis and melting process and also to study the response of snow and sea-ice cover extent in the Polar Regions to a climate forcing such as global warming. This paper will summarize the SGLI cryospheric products and validation plans.

Dual-frequency precipitation radar (DPR) development on the global precipitation measurement (GPM) core observatory

Masahiro Kojima, Takeshi Miura, Kinji Furukawa, Yasutoshi Hyakusoku, Takayuki Ishikiri, Hiroki Kai, Japan Aerospace Exploration Agency (Japan); Toshio Iguchi, Hiroshi Hanado, Katsuhito Nakagawa, National Institute of Information and Communications Technology (Japan)

The Dual-frequency Precipitation Radar (DPR) on the Global Precipitation Measurement (GPM) core observatory is developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). GPM objectives is to observe global precipitation more frequently and accurately. GPM contributes to climate and water cycle change studies, flood prediction and numerical weather forecast. GPM consists of GPM core observatory and constellation satellites carrying microwave radiometers (MWRs) and/or sounders (MWSs). The frequent measurement will be achieved by constellation satellites, and the accurate measurement will be achieved by DPR with high sensitivity and dual frequency capability. GPM core observatory is jointly developed by National Aeronautics and Space Administration (NASA) and JAXA. NASA is developing the satellite bus and GPM microwave radiometer (GMI), and JAXA is developing DPR. GPM algorithms for data processing are developed jointly. The DPR consists of Ku-band (13.6 GHz) radar suitable for heavy rainfall in the tropical region, and Ka-band (35.55 GHz) radar suitable for light rainfall in higher latitude region. Drop size distribution information will be derived which contributes to the improvement of rainfall estimate accuracy. DPR will also play a key role to improve rainfall estimation accuracy of constellation satellites. DPR proto-flight test at JAXA Tsukuba space center is finished and it is delivered to NASA for integration to the GPM observatory. In this paper, DPR PFT test result at Tsukuba space center, DPR status in the GPM observatory environmental test, and DPR on-orbit calibration plan will be presented.
EarthCARE mission in Japan and CPR development status

Toshiyoshi Kimura, Hirotaka Nakatsuka, Yoshihiro Seki, Gaku Kadosaki, Yoshiya Iide, Kazuyuki Okada, Jun Yamaguchi, Japan Aerospace Exploration Agency (Japan); Nobuhiro Takahashi, Yuichi Ohno, Hiroaki Horie, Kenji Satoh, National Institute of Information and Communications Technology (Japan) and Japan Aerospace Exploration Agency (Japan)

EarthCARE is the joint mission between ESA and Japan to observe global profile of cloud and aerosol. The mission is expected to reveal aerosol and cloud interaction quantitatively, which is still most uncertain factor of numerical climate model, using LIDAR and W-band Doppler Radar. The radar named Cloud Profiling Radar (CPR), is under development by JAXA and NICT in Japan. CPR is the first Radar to provide Doppler measurement of cloud particles up/down draft, using pulse pair method. Also, it has the highest sensitivity of cloud particles; -35dBZ. LIDER, which is under development by ESA, has polarized channels at ultra violet with hyper spectral filter. The filter enables direct measurement of Mie and Rayleigh scatter signal, independently. Each instrument has very unique capability to produce new or precise physical parameters. Moreover, synergy observation of RADAR and LIDAR has a further merit than single use in several points, such as larger dynamic range of cloud particle size or direct measurement of microphysical properties. For Doppler calibration, we have several approaches; roll manoeuvre on sea surface, multiple active radar calibrators from ground.

Currently CPR is in its Engineering Model Phase. After all RF and electrical component tests, CPR started its first electrical system integration test and will proceed to system RF characteristics test, toward launch in 2015.

Calibration and characterization concept of EarthCARE cloud profiling radar

Hirotaka Nakatsuka, Japan Aerospace Exploration Agency (Japan)

The cloud profiling radar (CPR) for the Earth, Clouds, Aerosols and Radiation Explorer (EarthCARE) mission, which is currently planned to be launched in 2015, has been jointly developed by JAXA and NICT in Japan. CPR is a millimeter-wave radar and has a large antenna reflector in order to achieve much higher sensitivity to cloud particles. The effectiveness of CPR has been already demonstrated by CloudSat. Following this success, CPR on board EarthCARE is expected to bring new important information on various clouds on Earth.

The unique feature of EarthCARE CPR is vertical Doppler velocity measurement capability. Vertical Doppler velocity measurement is very attractive function from the science point of view, because vertical motions of cloud particles are related with cloud microphysics and dynamics. However, from engineering point of view, Doppler measurement from satellite is quite challenging Technology.

In order to maintain and ensure the CPR performance, several types of calibration data will be obtained by CPR. Overall performance of CPR is checked by Active Radar Calibrator (ARC) equipped on the ground (CPR in External Calibration mode). ARC is used to check the CPR transmitter performance (ARC in receiver mode) and receiver performance (ARC in transmitter mode) as well as overall performance (ARC in transponder mode with delay to avoid the contamination with ground echo).

This paper will present the study results of the calibration and characterization concept of EarthCARE Cloud Profiling Radar and the preliminary external calibration experiment by using the ARC.

Current status of the JAXA/EarthCARE algorithm development and production model

Riko Oki, Takui Kubota, Maki Hirakata, Satoru Fukuda, Tomoyuki Nomaki, Toshiyoshi Kimura, Japan Aerospace Exploration Agency (Japan); Teruyuki Nakajima, The Univ. of Tokyo (Japan)

EarthCARE (Earth Clouds, Aerosols, and Radiation Explorer) is a joint Japanese-European mission, and the mission is designed to produce the maximum synergistic collaboration of European and Japanese science teams. For Level 2 and higher data products, Japan originally develops the algorithms to release as Japanese products from JAXA, although continuous exchanges of information will be conducted between Japan and Europe through the Joint Algorithm Development Endeavor (JADE). The JAXA/EarthCARE algorithm development team as Prof. T. Nakajima (Univ. of Tokyo) as the lead scientist consists of Prof. H. Okamoto (Kyushu Univ.) and Mr. Y. Ohno (NICT) for CPR; Dr. T. Nishizawa (NIES) for ATLD; Prof. T.Y. Nakajima (Tokai Univ.) for MSI; Prof. H. Okamoto for CPR-ATLD synergy and CPR-ATLD-MSI synergy; Prof. M. Satoh (Univ. of Tokyo) for model simulation; and Prof. T. Nakajima (Univ. of Tokyo) for Four-Sensor Synergy Algorithm. The Japanese product list of EarthCARE was determined in JAXA mission and will be introduced. JAXA standard products will be processed and released from JAXA Mission Operations System Office (MOS).

Conceptual study of the future cloud-precipitation observation mission from space

Nobuhiro Takahashi, National Institute of Information and Communications Technology (Japan); Misako Kachi, Takui Kubota, Kinji Furukawa, Japan Aerospace Exploration Agency (Japan)

The Tropical Rainfall Measuring Mission (TRMM) has been providing reliable global precipitation data since its launch in 1997. It is expected that good handover to the Global Precipitation Measurement (GPM) mission at around early 2014 and GPM is expected to operate 5 years and to accumulate a reliable global long precipitation record. Currently, the dual frequency precipitation radar (DPR), one of the major instruments onboard GPM core satellite, has been developed. Although about twenty years global precipitation record will be obtained by the end of the GPM mission, there are still high expectation for the longer precipitation record from the viewpoints of climate change monitoring, evaluation of the numerical prediction models on global warming, and so on. For these reasons, future precipitation measurement mission was started to study targeting the successive observation to GPM. Mission requirements are gathered from GPM science community and are consolidated to the mission concept during this study. The most important scientific target is the cloud-precipitation processes study which is one of the uncovered topics in GPM mission. To fulfill this requirement, cloud and precipitation observation capability is required for this mission. It requires both precipitation radar like as GPM/DPR and a cloud profiling radar with scanning capability or upgrading the DPR to the higher sensitivity. Preliminary feasibility study was done with the help from JAXA’s system engineering group. For the engineering, technological challenge are defined to as scanning capability of W-band cloud radar and improvement of the sensitivity of the precipitation radar.
Spatio-temporal variability of surface rainfall over the tropics studied from global cloud-system resolving model and satellite observations

Toshiro Inoue, The Univ. of Tokyo (Japan); Kavirajan Rajendran, C-ICMACS (India); Masaki Satoh, The Univ. of Tokyo (Japan) and Japan Agency for Marine-Earth Science and Technology (Japan); Hiroaki Miura, The Univ. of Tokyo (Japan)

Global cloud-system-resolving model (Non-hydrostatic Icosahedral Atmospheric Model; NICAM) simulated the semi-diurnal variation of surface rainfall over tropical land area. Both TRMM/PR and TMI climatological data show the semi-diurnal peaks over land area with primary peak in the afternoon and secondary peak in the morning. Convective rain classified by PR is dominant in the afternoon and stratiform rain is more than convective rain in the morning peak. We also found clear semi-diurnal variation in the mean size of deep convection (DC) over southern Africa. The rainfall peak time in the afternoon over southern Africa corresponds to the time when a large number of developing stage (smaller size) DC occurred simultaneously. This temporal variation of number and mean size of DC is well represented as DC defined by OLR simulated in NICAM.

Absorption coefficient of CDOM in Zhejiang coastal waters

Guannan Fan, Chen Peng, The Second Institute of Oceanography, SOA (China)

Chromophoric dissolved organic matter (CDOM) exists in all natural waters. Researches on optical properties of CDOM play an important role in ocean color remote sensing retrieval. The optical properties of CDOM in Zhejiang coastal waters were investigated from August 18, 2009 to June 9, 2011 covering four seasons. Based on the measured data, the distribution of the absorption coefficient of CDOM was analyzed. The results showed that absorption coefficient at 440 nm (a(440)) decreased with the offshore direction, and the relatively high value of a(440) was observed generally in the coastal waters and low value in the adjacent waters. The distribution reflected the terrigenous origin characteristics of CDOM. The relationship between salinity and a(440) of the four seasons was discussed. The results demonstrated that a(440) had a significant negative linear relationship with the salinity. That is to say, CDOM took on the conservative behavior in the research region.

Precipitation characteristics around Bangladesh revealed by TRMM data

Kenji Nakamura, Fumie A. Furuzawa, Masanori Nishikawa, Dibas Shrestha, Nagoya Univ. (Japan)

Bangladesh region is interesting regions in a core region of the Asian monsoon. The Bangladesh region is very flat region facing to the Bay of Bengal. The precipitation characteristics are studied using the long-term Tropical Rainfall Measuring Mission (TRMM) data. Over the Bangladesh, the stability of the atmosphere seems to affect the precipitation system in the vertical profiles. In the pre-monsoon season, rain rate increases with height in the upper part of the profile, while in the mature monsoon season, rain rate is nearly constant in the lower part of the profile. The structure of precipitation system is more persistent and homogenous in the mature monsoon season. The rain top is higher in pre-monsoon season than in mature monsoon season. The rain total is generally determined by rain frequency. The horizontal size of the precipitation systems is larger for pre-monsoon season than for mature monsoon season. In other words, the precipitation system is small but many in the mature monsoon season. This fact may be explained that the atmosphere is sufficiently humid to be easily triggered by small liftings. These characteristics are reflected in the rain retrieval biases in precipitation radar and microwave radiometers in space.

Ensemble-based variational assimilation method to incorporate microwave imager brightness temperatures into a cloud-resolving model

Kazumasa Aonashi, Meteorological Research Institute (Japan)

The goal of the present study is to develop a method to assimilate Microwave Imager (MII) brightness temperatures (TBs) into Cloud-Resolving Models (CRM). To address the non-linear relationship of TBs to the state variables of CRM and the flow-dependency of the CRM forecast error covariance, I adopted an Ensemble-based variational data assimilation method (EnVA). In this presentation, I will report our recent studies on the following problems in EnVA: 1) Large-
scale displacement errors of rainy areas between the observation and the CRM forecasts; 2) Serious sampling error of cloud-physical variables because they were confined in rainy areas. In order to solve the displacement error problem, I developed the EnVA that used Ensemble forecasts with displacement error correction. I applied this method to assimilate TMI (TRMM Microwave Imager) low-frequency TBs (10, 19, and 21 GHz with vertical polarization) for a Typhoon case around Okinawa (9th June 2004). In this case, TBs calculated from the CRM Ensemble forecasts had large-scale displacement errors, in particular over south-east and east of the Typhoon. The results of the assimilation experiments showed that the assimilation of TMI TBs alleviated the large-scale displacement errors and improved the CRM forecasts.

In order to alleviate the sampling error, I am introducing the following ideas to the EnVA: 1) Use of ensemble forecasts at neighboring grid points; 2) Classification of CRM variables and assumption of zero cross correlation between different classes.

8529-4, Session 1
Is the simulated increasing trend of dry static stability true or not?
Masato Sugi, Japan Agency for Marine-Earth Science and Technology (Japan)

Recent climate models consistently project a decreasing trend of global tropical cyclone (TC) frequency in the future due to global warming. We recently conducted a set of 228 year-long simulations from 1969 to 2099 using a high-resolution MRF ACOM3.2 with prescribed sea surface temperature and green house gas concentration. In this simulation a decreasing trend of global TC frequency is found not only in the future but also in the past during the twentieth century. It has been pointed out that the decreasing trend of TC frequency is closely related to a decreasing trend of upward mass flux in the tropics. It has been further argued that the decreasing trend of upward mass flux is in turn closely related to an increasing trend of dry static stability (larger warming in the upper troposphere than in the lower troposphere). Both decreasing trend of upward mass flux and increasing trend of dry static stability are simulated in all climate models. However, some observational studies indicated that the dry static stability was increasing at much smaller rate than the climate models or even decreasing during the last 30 years. Is there something wrong in all climate models? Or, is there any problem in the satellite data? In this paper, we will discuss possible causes of this apparent discrepancy between the observations and models.

8529-5, Session 1
Modification of hurricane Helene (2006) development by dust-radiation-cloud interactions
Shu-Hua Chen, Univ. of California, Davis (United States); C. T. Cheng, National Science and Technology Ctr. for Disaster Reduction (Taiwan); Jen-Ping Chen, Y. C. Lin, National Taiwan Univ. (Taiwan); H. H. Lee, Yi-Chin Liu, Univ. of California, Davis (United States); I. C. Tsai, National Taiwan Univ. (Taiwan)

Saharan dust can modify the Saharan Air Layer (SAL) and its environment by changing the energy budget through direct and indirect radiative forcing. Scattering and absorption of radiation by suspended dust directly modifies the energy budget in the atmosphere and at the surface. Smaller dust particles can remain suspended in the air for prolonged periods and propagate over the Atlantic Ocean along with SAL. These fine particles can reach an altitude of 8-9 km, where they nucleate ice crystals and transform cloud microphysical properties, indirectly changing the energy budget. Thus, the dust within the air mass is likely to affect the evolution of hurricane properties, life cycles, and the corresponding cloud systems through the dust-cloud-radiation interactions.

A tracer model based on the Weather Research and Forecasting model (named WRFT) was developed to study the influence of dust-radiation-microphysics effects on hurricane activities. The dust-radiation effects and a two-moment microphysics scheme with dust particles acting as ice nuclei were implemented into WRFT. In this work, Hurricane Helene (2006), during 10-18 September 2006, was studied. Six high-resolution numerical experiments were conducted with the combinations of activating/deactivating dust-radiation and/or dust-microphysics processes, as well as different dust emissions. Results from these six experiments are compared to investigate the influence of dust-radiation-microphysics processes on Helene development.

8529-6, Session 1
An approach to the simulation of polarized infrared remotely sensed data in the design of novel sensor
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The consistent simulation of remote sensing data is an important task and sometimes the only way for the design and optimization of novel sensor and the evaluation of the capabilities of the whole sensor system. Polarized infrared remotely sensing data could provide more abundant information than traditionally multispectral infrared remotely sensed data and thus greatly extend the range of remote sensing applications. Unfortunately, polarized infrared remotely sensing data are much more complex and difficult to acquire and process not available prior to the development of operational polarized infrared instruments, especially in the design stage of a new sensor, while large amounts of accumulated multispectral remotely sensing data have been acquired around the world over the past several decades. With the development of the Fresnel equations for polarized and the vector radiative transfer for the electromagnetic wave theory, it is reasonable to examine means of using multispectral data as input, vector radiative equations combines all the polarimetric attributes of infrared emission to simulate polarized infrared data. A method based on the vector radiative transfer of light is proposed to simulate polarized infrared data for a given multispectral data with specified polarized contribution model of land surface. This method involves the observed land surface, the atmosphere and a Stokes parameter model of the polarized sensor system. In this paper, the benefit of using the vector radiative transfer approach to simulate polarized imaging is demonstrated.

8529-7, Session 2
Satellite-based 3D structure of cloud and aerosols over the Indian Monsoon region: implications for aerosol-cloud interaction
Sagnik Dey, Nidhi Nidhi, Kamalaika Sengupta, George Basil, Parul Srivastava, Indian Institute of Technology Delhi (India)

Aerosol-cloud interaction is critical in the Indian Subcontinent because aerosols are hypothesized to impact the monsoon circulation (and hence precipitation) that has a major influence on the region’s economy. Climate models continue to have large error in resolving this issue because of lack of a robust statistics of 3-D structure of aerosol and cloud fields. In this study, we analyzed CALIPSO data during 2006-2010 to establish climatology of aerosol vertical distribution over the Indian Subcontinent and examine their space-time variability along with vertical distributions of clouds derived from MISR and ISCCP data. A multi-layer cloud field has been observed by comparing the MISR and ISCCP retrievals. Dominance of low clouds is observed over the oceans throughout the year, while the high clouds start developing in the monsoon months. The core Indian monsoon region shows strong seasonality in cloud cover (and vertical distribution). Dominance of low clouds in close proximity to high aerosol loading has implications for aerosol-cloud interaction. Dominance of high clouds lead to a strong net TOA cooling due to low longwave warming compared to large shortwave cooling, while dominance of low clouds lead to near cancellation of TOA shortwave cooling by longwave warming. Temporal evolution of cloud vertical structure and microphysical properties within an entire monsoon season are also examined in view of the active and break phases. These results will help improve the simulations of regional hydroclimate and their treatment of aerosol-cloud interaction.
8529-8, Session 2

Assimilation of satellite data in south Asian regional reanalysis
Sarat C. Kar, National Ctr. for Medium Range Weather Forecasting (India)

In recent years, several global retrospective analysis (reanalysis) datasets have been available. Our studies show that there are several inconsistencies among the global reanalysis datasets over the Indian subcontinent. The hydroclimate in the region is not represented well by these datasets and they do not agree well with available observations. The South Asian Regional Reanalysis (SARR) project is being implemented as an collaborative Indo-US effort at NCMRWF to reduce the gap in our knowledge on climate variability and climate change over South Asia. Main objective of the project is to provide an atmosphere-land-surface state description where consistency between circulation and hydroclimate components is assured. The SARR project aims to exploit the high spatio-temporal resolution of satellite observations; generate unique synthesis of conventional and remotely sensed data using state-of-the-art atmosphere/land-surface models. Currently the SARR pilot phase experiments are being carried out. For the purpose, WRF ARW 3D-Var and AIRS IASI data have been used. Whereas final SARR production runs shall be carried out at 18km horizontal resolution, the pilot runs are at 25km. Experiments have been carried out with various conventional data as well as satellite data (both direct radiance as well as derived products). Additional experiments have been carried out using the grid point statistical interpolation (GSI) with the WRF model and a comparison has been made with that of WRF 3DVar. Further improvement shall come from rainfall assimilation.

8529-9, Session 2

Use of hyperspectral observations at Indian Space Research Organization (ISRO): simulation of ISRO’s future satellite observations and their assimilation in mesoscale NWP models
Chandra M. Kishatwal, Pradeep K. Thapliyal, Indian Space Research Organization (India); Randhir Singh, Indian Space Research Organisation (India); Pradeep K. Pal, Indian Space Research Organization (India)

Hyperspectral measurements have shown significant improvement in the atmospheric sounding capability, both in terms of accuracy and vertical resolution. India is planning to launch hyperspectral sounder in future to improve the atmospheric profiling capabilities. At ISRO, we are utilizing the hyperspectral sounder observations for the following applications: (i) GSICS application: Use of hyperspectral sounder radiances from AIRS and IASI for inter-satellite calibration of infrared sensors onboard Indian geostationary satellites, (ii) Algorithm testing for INSAT-3D: IASI radiances are used to synthesise radiances from INSAT-3D (ISRO’s future geostationary satellite with sounding capability) Sounder by convolving the IASI radiances over INSAT-3D SRFs. A bias correction routine has been developed to remove the convolution bias. The retrieval algorithm for INSAT-3D Sounder is being tested using these synthetic radiances. (iii) System Definition Studies: IASI-based synthetic broadband radiances being used to propose an optimum configuration for sounder onboard future Indian geostationary satellites. (iv) Weather Applications: The hyperspectral sounding observations provide very high vertical resolution of atmospheric temperature and humidity profiles. High vertical resolution information from AIRS and IASI have been used over Indian region to detect the temperature inversion that often leads to the fog conditions. (v) Assimilation in mesoscale models: Hyperspectral radiances are being used in WRF model. One of the main objectives of these studies is to define an optimum set of channels to improve the short range prediction over hot and humid Indian subcontinent.

8529-10, Session 2

Future Doppler lidar wind measurement from space in Japan
Shoken Ishii, National Institute of Information and Communications Technology (Japan); Toshiki Iwasaki, Tohoku Univ. (Japan); Masaki Sato, The Univ. of Tokyo (Jordan); Riko Oki, Japan Aerospace Exploration Agency (Jordan); Kozo Okamoto, Meteorological Research Institute (Japan); Philippe Baron, National Institute of Information and Communications Technology (Japan); Tomoaki Nishizawa, National Institute for Environmental Studies (Japan)

Wind profile is fundamental in many atmospheric issues, such as numerical weather prediction, global climate modeling, atmospheric transport of many substances, and investigation of local and mesoscale weather phenomena. Many sensors, such as radiosonde, windprofiler, and Doppler lidar, have been developed for the wind measurement. Radiosonde and windprofiler are used to obtain wind profiles. Roughly 900 weather stations launch radiosondes to obtain profiles of pressure, wind, temperature, and humidity. Most of the weather stations are on land, while the stations on the sea are very sparse. Spaceborne visible and infrared imagers and microwave scatterometers can obtain wind data only at a specific altitude. Current wind observations are not enough and need to reduce errors to improve the wind reliability in the global climate model and weather prediction. Many scientific groups anticipate the realization of a global observation system for making the three-dimensional wind measurement. The spaceborne Doppler lidar is regarded as one of the candidate sensors for the global wind measurements. The working group on Japanese spaceborne Doppler Lidar has been established to realize for making wind measurement from space. In this paper, we describe the activities and goals of the working group on Japanese Spaceborne Doppler Lidar.

8529-11, Session 3

Observing system simulation experiments at Joint Center for Satellite Data Assimilation
Michiko Masutani, National Oceanic and Atmospheric Administration (United States); Lars Peter Rishøjgaard, Joint Ctr. for Satellite Data Assimilation (United States); John S. Woollen, National Oceanic and Atmospheric Administration (United States); Sean Casey, Joint Ctr. for Satellite Data Assimilation (United States)

An internationally collaborative effort for Observing System Simulation Experiments (OSSE) called Joint OSSE, was formed during past several years and Joint Center for Satellite Data Assimilation (JCSDA) is taking a lead for the Joint OSSES. Nature Run, truth for OSSE, must be produced by the state of the art forecast model. The Joint OSSE Nature Run was produced by the European Center for Medium-Range Weather Forecasts (ECMWF). This Nature Run covers a 13 month period at T511 horizontal resolution with 91 vertical levels. For OSSES, all major observations used for the data assimilation have to be simulated as a control observation in addition to the observations to be tested by OSSES. Simulation of control observations and OSSE calibration are the most significant initial investments for a OSSE before it can be used to evaluate data impact of future instruments. Control observation were simulated at NOAA from the Nature run and saved in BUFR format. Nature run and simulated data are made available from NASA portal and NCAR for international collaborative Joint OSSE.

The first OSSE at JCSDA focused on evaluation of the space based Doper Wind Lidar (DWL), which is a costly observing system provide three dimensional global wind profile. OSSE results showed significant improvement in both intensity and track for hurricane forecasts. In 2010, National Polar-orbiting Operational Environmental Satellite System (NPOESS) was divided into Joint Polar Satellite System (JPSS) and Defense Weather Satellite System (DWSS). Currently JCSDA is working on OSSES to help planning for JPSS and DWSS.
8529-12, Session 3

Scatterometer observations of the pre-monsoon transition
Ziad S. Haddad, Jet Propulsion Lab. (United States)

Our recent analysis of the QuikScat ocean vector wind data off the western coast of India from 1999 to 2009 has allowed us to define an objective “daily flow” direction (DFD) whose time series has revealed several very interesting features of the Indian monsoon. First, the intra-annual evolution of the DFD consistently shows three coherent phases: the wet monsoon during which DFD is consistently onshore (with a well-defined onshore) followed by the dry monsoon (with a steady and consistently short transition) during which the wind is consistently offshore, followed by a third transitional dry-to-wet-monsoon season during which the sign and amplitude of the DFD can change substantially from day to day. Most interesting is the fact that the land surface temperatures obtained over the southern cone of the subcontinent from MERRA show that the temperature maximum is achieved within the second half of this transitional season: in other words, every year, the land surface cooling begins weeks before the onset of the wet monsoon. This talk will describe the observations and our modeling effort.

8529-13, Session 3

Integrated instrument simulator suites for Earth science
Simone Tanelli, Noppanis Niamsuwan, Jet Propulsion Lab. (United States); Wei-Kwo Tao, Toshihsia Matsui, NASA Goddard Space Flight Center (United States); Chris A Hostetler, Johnathan W Hair, Carolyn F Butler, NASA Langley Research Center (United States); Kwo-Sen Kuo, Caelum Research Corporation (United States); Michael P Johnson, Joseph C Jacob, Jet Propulsion Lab. (United States); Leung Tsang, University of Washington (United States); Khawaja Shams, Sermaksar Januwatanadilok, Shadi Oveisgharan, Marc Simard, Francis J Turk, Jet Propulsion Lab. (United States)

The Instrument Simulator Suite for Atmospheric Remote Sensing is a modular framework of forward simulation tools for remote sensing of Earth’s Atmosphere from space. It was developed to enable science users to perform simulations based on atmospheric and land surface models, and to rapidly integrate in a broad framework any experimental or innovative tools that they may have developed in this context. ISSARS relies on a web-based graphic user interface, and a three-stage processing strategy to generate simulated measurements. The user has full control over a wide range of customizations both in terms of a priori assumptions and in terms of specific solvers or models used to calculate the measured signals.

A follow-on project, the Unified Simulator for Earth Remote Sensing (USERS), will expand ISSARS by accommodating a new library of state of the art models for the scattering and emission properties of layered surface (e.g., soil moisture, vegetation, snow and ice, subsurface layers); implement a direct, automated OSSE (Observing System Simulation Experiment) interface to enable process-to-process functionality via web services; and expand its processing capabilities by enabling its function in cloud computing environment.

This presentation will demonstrate the general architecture, the configuration procedures and illustrate some sample products and the fundamental interface requirements for modules candidate for integration.

8529-14, Session 3

Impacts of enhanced CCN on the organization of convection and recent reduced counts of monsoon depressions
Tiruvalam N. Krishnamurti, Andrew Martin, Ruby Krishnamurti, Anu Simon, Aype Thomas, Vinay Kumar, The Florida State Univ. (United States)

Monsoon depressions, with a horizontal scale of 2000 to 3000 km, are known to be baroclinic disturbances driven by deep convection that carry a very large vertical slope towards cold air. Deep convection is organized around the scale of the monsoon depression. The maintenance of the monsoon depression follows Murthy and Arakawa’s analysis i.e. the generation of kinetic energy on the scale of the monsoon depression is largely governed by the three scale covariances of heating and temperature and of vertical velocity and temperature over the region of the monsoon depression. There are normally about 6 to 8 monsoon depressions during a summer monsoon season. Recent years 2009, 2010 and 2011 saw very few (3, 1 and 1) respectively of monsoon depressions.

The best numerical models such as those from ECMWF and UFS (GFS) carried many false alarms in their, 3 to 5 day, forecasts and the seasonal counts for their forecasts; were more like 6 to 8 disturbances. These are fairly comprehensive models that carry vast data sets (surrogate and satellite based), detailed data assimilation, and are run at very high resolutions (T1279 L91 and T574 L64 respectively). These models also carry complete and detailed array of physical parameterizations. These models represent the horizontal and vertical shear of the monsoon flows quite reasonably at these resolutions; they represent the effect of convection from the parameterization of cumulus convection. The monsoon depression is well resolved by the horizontal resolution of these models (at 15 and 35km). An entire season full of false alarms in their forecasts by these models leads us to suggest that some additional important ingredient is missing in these current best models. This research proposal addresses the investigation of effects of pollution on the enhancement of cloud condensation nuclei and the resulting disruption of the organization of convection in monsoon depressions. Ramanathan work points to an overall increase of pollution over the Asian monsoon belt. Our separate studies makes use of a high resolution mesoscale model and a WRF/Chem model under different sensitivity scenarios and expand the scope of this investigation over an entire monsoon season. We present some preliminary results for these disruptions for the organization of convection resulting in the non formation of depressions. Near normal rainfall over India in many recent years have been noted even when monsoon depressions were largely absent but there were present a large number of monsoon lows. The disruption of the organization of convection of monsoon depressions is shown to weaken and form monsoon lows. The latter carry an abundance of rains. There thus appears to be a possible impact of pollution on the rainfall distributions of monsoon lows that is also illustrated in this study.

8529-15, Session 3

Modeling of forecast sensitivity on the march of monsoon isochrones from Kerala to New Delhi, the first 25 days
Anu Simon, Tiruvalam N. Krishnamurti, Thomas Pynadath Aype, Akhilesh K. Mishra, The Florida State Univ. (United States); Dev Sikka, Consultant Meteorologist (India); Dev Niyogi, Purdue Univ. (United States); Arindam Chakraborty, Indian Institute of Science (India); Li Li, U.S. Naval Research Lab. (United States)

This study addresses observational and modeling sensitivity on the march of the onset isochrones of the Indian summer monsoon. The first 25 days of the passage of the isochrones of monsoon onset is of great scientific interest. Surface and satellite-based datasets are used for high resolution modeling of the impact the motion of the onset isochrones from Kerala to New Delhi. These include the asymmetries across the isochrone such as soil moisture and its temporal variability, moistening of the dry soil to the immediate north of the isochrone by non-convective antl rains, formation of newly forming cloud elements to the immediate north of the isochrone. The region, immediate north of the isochrone, is shown to carry a spread of buoyancy elements. As these new elements grow, they are continually being steered by the divergent circulations of the parent isochrone to the north and
eventually to the northwest. CLOUDSAT was extremely useful for identifying the asymmetric cloud structures across the isochrone. In the modeling sensitivity studies, the authors used a mesoscale WRF model to examine days 1 to 25 of forecasts of the onset isochrone. Prediction experiments were first modeled during normal, dry, and wet Indian monsoon seasons using default values of model parameters. This study was extended to determine the effects of changes in soil moisture and non-convective rainfall parameterizations, these are parameters suggested by the satellite observations. These sensitivity experiments show that the motion of the isochrones from Kerala to New Delhi are very sensitive to the parameterization of soil moisture and non-convective anvil rains immediately north of the isochrone.

8529-16, Session 3

Estimation of regional surface CO2 fluxes with GOSAT observations using two inverse modeling approaches

Shamil Maksyutov, Hiroshi Takagi, Dmitry A. Belikov, Tazu Saeki, National Institute for Environmental Studies (Japan); Ruslan Zhuravlev, Alexander Ganshin, Central Aerological Observatory (Russian Federation); Makoto Saito, Lab. des Sciences du Climat et de l’Environnement (France); Vinu Valsala, Indian Institute of Tropical Meteorology (India); Tom Oda, Colorado State Univ. (United States); Ryu Saito, Japan Agency for Marine-Earth Science and Technology (Japan); Sergey Oshchepkov, Andrey I. Bril, Yukio Yoshida, National Institute for Environmental Studies (Japan); Alexander Lukyanov, Central Aerological Observatory (Russian Federation); Robert J. Andres, Oak Ridge National Lab. (United States); Thomas Conway, Pieter Tans, NOAA/ESRL (United States); Tatsuya Yokota, National Institute for Environmental Studies (Japan)

Inverse estimation of surface CO2 fluxes using atmospheric transport model plus ground-based and GOSAT observations is reported. The NIES-retrieved CO2 column mixing ratio (XCO2) and column averaging kernel are provided by GOSAT Level 2 product version 2 and PPD-FDOAS method. Monthly mean CO2 fluxes for 64 regions are estimated together with a global mean offset between GOSAT data and ground-based. We used the fixed-lag Kalman smoother to infer monthly fluxes for 42 sub-continenal terrestrial regions and 22 oceanic basins. We estimate fluxes and compare results obtained by two approaches. In basic approach adopted in GOSAT Level 4 product we use aggregation of the GOSAT observations into monthly mean over 5x5 degree grids and fluxes are estimated independently for each region, and NIES atmospheric transport model is used for forward simulation. In the alternative method the model-observation misfit is estimated for each region by using a semi-empirical approach to calculate the seasonal cycle of the atmospheric CO2. Monthly ocean-atmosphere CO2 fluxes are produced with an ocean pCO2 data assimilation system. Biomass burning fluxes were provided by the Global Fire Emissions Database (GFED); and monthly fossil fuel CO2 emissions are estimated with ODIAC inventory. The results of the analyzing one year of the GOSAT data suggest that when both GOSAT and ground-based data are used together the fluxes change compared to using only ground-based data in the tropical and other remote regions, for those regions flux uncertainties are reduced when compared to ground-based data only case. Version 2.0 of L2 XCO2 has several advantages as compared to previous version 1.xx, providing more data and less scatter. The fluxes appear more reasonable for many regions and seasons, there is a need for improving the retrieval, data filtering and the inverse modeling method to reduce estimated flux anomalies visible in some areas. We also observe that application of spatial flux correlations reduces flux anomalies.
Evaluating the spatial and temporal solar energy potential in South Korea
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Recent issues of climate changes and natural disasters have brought many changes in energy utilization. Especially due to the Japan’s earthquake and tsunami, potential of nuclear power have made negative. And thus many countries are looking for a new renewable energy that can replace. Of which solar energy has emerged as a useful alternative. Under these circumstances, it is highly desirable that detailed information about the availability of solar radiation on the surface is essential for the optimum design and study of solar energy systems. And its components at a given location are very essential. Hence the solar radiation data is one of the key parameters required to be monitored at any meteorological station. But solar radiation measurements are not easily available due to the cost and maintenance requirements of the measuring equipment. Therefore, solar resource modeling or mapping is one of the essential tools for proper design, planning, maintenance and pricing of solar energy system. In this study, the feasibility of a regression model using image fusion for the prediction of solar energy potential in Republic of Korea was investigated. Landsat, meteorological and geographical data of 34 cities in South Korea for period of 10 years (2000-2010) were used. Meteorological and geographical data (latitude, longitude, altitude, month, sunshine duration, temperature, and relative humidity) were used as inputs to the model, while the regional solar radiation was used as the output of the model. The model for evaluating the spatial and temporal solar radiation was executed for South Korea. The annual mean solar radiation estimates in South Korea vary from a minimum of 5.2 MJ/m²/day to a maximum of 19.1 MJ/m²/day. Our proposed annual mean solar radiation is 13.0 MJ/m²/day. These compare favorably with the observed data as expected. This study has shown that a simple method can accurately predict solar radiation potential in South Korea.
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