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Editor's Corner

Steve Platnick
EOS Senior Project Scientist

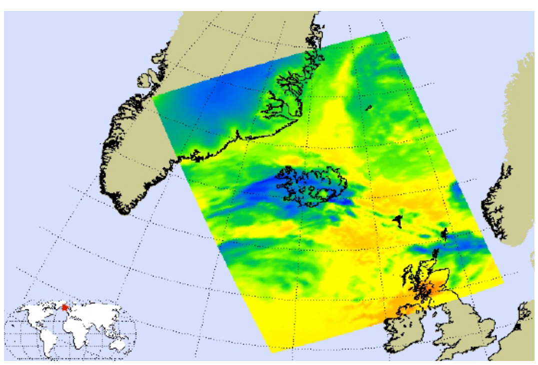
In our last issue, we reported that from October 25-28, 2010 over 600 people gathered in New Orleans, LA to participate in the second A-Train Symposium. It is fitting that such an event took place in a city well known for its unique blend of culture and style (jazz music, Cajun cuisine, etc.). Similarly, the A-Train blends together a variety of satellite missions—each with its own unique measurements and objectives—to achieve a unique multiplatform scientific observatory. Through careful planning between NASA and its international partners, four[1] (eventually seven) missions currently fly in a tight formation, crossing the equator within about a seven-minute window at 1:30 PM (and also 1:30 AM)—and thus referred to as the *Afternoon Constellation.* New science investigations made possible by A-Train synergy are rapidly advancing our knowledge about a variety of topics important for understanding Earth system science. The symposium was a wonderful opportunity for the community to gather and learn from one another about the width and breadth of this new work. A compre-

[1] This number doesn't include PARASOL, which was allowed to begin drifting out of the A-Train formation in December 2009 and now only occasionally intersects with it.

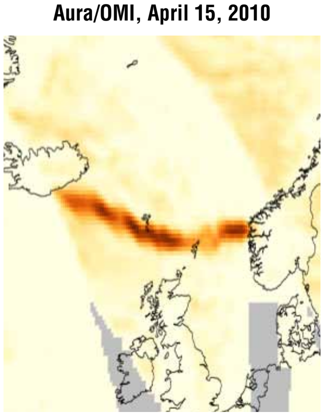
continued on page 2

True Color
Aqua/MODIS, April 17, 2010

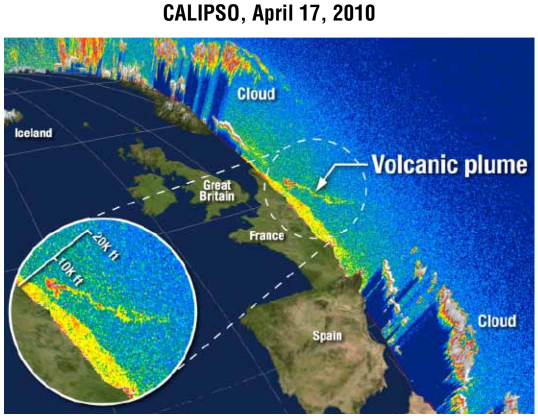
Brightness Temperature
Aqua/AIRS April 15, 2010



Aerosol Index
Aura/OMI, April 15, 2010



Vertical Profile
CALIPSO, April 17, 2010



All of the A-Train's instruments view the same area within about a seven-minute window and provide a powerful new tool for examining natural and man-made disasters from space. The example here shows the Eyjafjallajökull volcanic eruption (in Iceland) from a variety of perspectives. **True Color** images [*top left*] combine visible and infrared measurements to give us a photo-like view of the volcano and ash cloud that is relatively familiar to us. **Brightness Temperature** [*top right*] is measured using an infrared instrument that cannot penetrate clouds. We can thus use these measurements to estimate the temperature at the top of clouds, and approximate their altitude. **Aerosol Index** [*bottom left*] is a mathematical method of estimating the amount of ash and other particles from an eruption, based on the way particles in the air affect the passage of visible or ultraviolet light through the atmosphere. The **Vertical Profile** image [*bottom right*] comes from lidar measurements where a pulse of light (visible and infrared) bounces off the plume and the return is used to create a three-dimensional profile. **Credit:** NASA

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eos.nasa.gov

In This Issue

hensive summary of the symposium appears on page 12 of this issue.

The newest member of the A-Train, Glory, is scheduled for launch on February 23 from Vandenberg Air Force Base in California. Glory, being launched on an Orbital Sciences Corp. *Taurus XL* rocket, carries the new Aerosol Polarimetry Sensor (APS) and an improved version of the sun-viewing Total Irradiance Monitor (TIM) that flies on the SORCE mission. We plan more coverage of Glory after it launches—hopefully in our next issue.

Also in this issue, we have an update on some of the latest research findings from one of the A-Train members, namely Aura—see page 8. These results were among others highlighted at several recent science team meetings. Aura is one of NASA's three large Earth Observing System missions and is dedicated to understanding the chemistry of our atmosphere. In addition, the Aura team has developed a full-color brochure called *Our Changing Atmosphere - Discoveries from EOS Aura* that also highlights some of these and other discoveries from Aura. (You can download a copy from the Aura web site—*aura.gsfc.nasa.gov/*.)

Related to these items, I would like to bring your attention to an A-Train website that the Project Science Office has created—*atrain.nasa.gov/*. Here you will find in one location a variety of information relevant to the various missions that compose the formation, including links to A-Train data archives, mission operations, recent news stories, relevant publications (e.g., fact sheets, brochures, writers' guides, etc.), multimedia (i.e., images, podcasts, vodcasts, stories), and other links. We need your help to keep the information on this site updated. If you're involved in any of the A-Train missions, and have not done so already, please take a look at the site. If you have any suggestions for additional content please let me know.

Congratulations go out to the CLARREO project, one of the Earth Science Decadal Survey's *Tier 1* missions, which passed its Mission Concept Review (MCR) at LaRC, the Center leading the CLARREO mission, on November 17, 2010. The MCR Review Board reported their findings to LaRC and GSFC Center management on December 17. The Board stated that the CLARREO team's concept met the baseline Level 1 science requirements, schedule constraints, and its cost cap and funding profile. In addition, the Board noted that the team had a *"strong understanding of science objectives and science requirements"* and that the team exhibited an exceptionally *"strong working relationship between science, project management, and engineering."* Only three Requests for Action (RFAs) were cited with an overall recommendation that *"The CLARREO mission has successfully demonstrated MCR maturity and should be approved to proceed to Phase A."* The team is currently preparing for Key Decision Point-A (KDP-A), which is tentatively scheduled for February 2011.

More recently, the DESDynI mission had its MCR on January 19–20 at JPL. The review looked at all elements of the mission, which includes separate spacecrafts for the radar and lidar instruments. While at the time of this writing, the review team has not had time to present its official report, including RFAs, it was unanimous by all review team members that the project met the MCR exit criteria and should proceed to Phase A.

With ICESat-2 and SMAP already in formulation, this represents an important milestone for the four *Tier 1* Decadal Survey missions.

On the education and public outreach front, some mission Project Scientists and *EarthSky* Communications have collaborated to produce a series of podcasts on NASA Earth Observing missions and the scientific data they provide. The 90-second and 8-minute podcasts feature interviews with leading NASA-funded scientists, who discuss current issues in Earth science and how satellite observations are helping to address these issues. The interviews have been broadcast on *EarthSky's* radio show, which reaches millions of listeners, and posted on the *EarthSky* site (*earthsky.org*). Scientists involved with the Aqua, ICESat, and Terra missions are just some of those who have been interviewed. To browse the podcast listings, go to *earthsky.org* and click on the "Water" or "Earth" headings. A "NASA Satellite Missions" section (*earthsky.org/featured-content/nasa-satellite-missions*) highlights some of the interviews. For a list of all interviews for a given mission, along with links to EarthSky, please visit the mission websites (Aqua: *aqua.nasa.gov/*; Terra: *terra.nasa.gov/media/index.php*; ICESat: *icesat.gsfc.nasa.gov/interviews.php*).

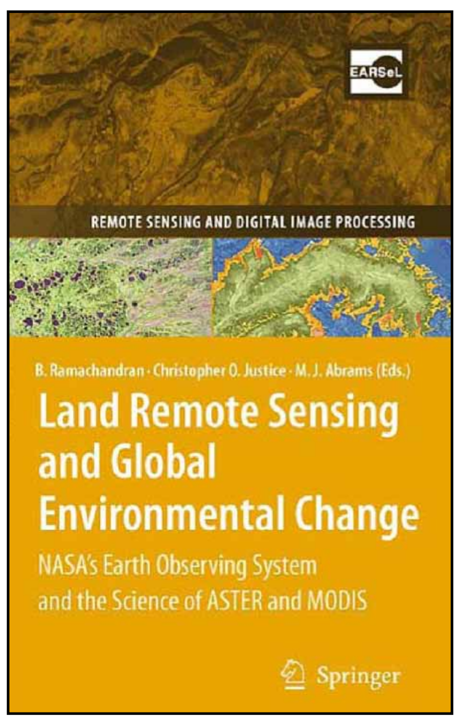
Finally, while *The Earth Observer* is a black & white publication, we use many images (e.g., from *The Earth Observatory* website—*earthobservatory.nasa.gov*) or other graphics that were originally in color. We have traditionally credited the source of our graphic and included a link to where the original color graphic can be found. (A 508-compliant *pdf* of each issue of *The Earth Observer* can be found at: *eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php*.)

While costs of printing the newsletter still prohibit us producing the print version in color, beginning with the January–February 2011 issue, the *pdf* version posted at our website will contain the color graphics. This will make it easier for readers to view the original color graphics in a single location. It also eliminates the need to include links with every graphic and thereby helps to streamline the captions.

This is a good opportunity to remind everyone of the ***Go Green*** option for receiving *The Earth Observer*. If at any time you would like to stop receiving the print copy of the newsletter and download your copy from the website—now complete with color graphics—you need only send **Steve Graham** (*steve.graham@nasa.gov*) an e-mail with the subject "Go Green." Your name and e-mail address will then be added to an electronic database and you will receive a bi-monthly message alerting you when a new issue of *The Earth Observer* is available for download. If you change your mind, the e-mail provides an option for resuming receipt of the printed version. ■

New Book Highlights ASTER and MODIS Land Remote Sensing-based Applications

The year 2009 marked the 10th anniversary of NASA Earth Observing System's (EOS) Terra platform's launch. In that decade, two EOS instruments, Moderate Resolution Imaging Spectroradiometer (MODIS), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) have contributed to several biophysical, geological, and geophysical applications. *Land Remote Sensing and Global Environmental Change* is an edited compendium published by Springer that specifically focuses on the terrestrial components of change based on the scientific knowledge derived from data produced by ASTER and MODIS. The primary audience for this book is Earth and environmental science researchers and professionals, including those who use land remote sensing data. For more information please visit: *www.springer.com/astronomy/extraterrestrial+physics%2C+space+sciences/book/978-1-4419-6748-0*



feature articles

Goddard DEVELOP Students: Using NASA Remote-sensing Technology to Study the Chesapeake Bay Watershed

Rachel Moore, DEVELOP National Program, Goddard Space Flight Center, Rachel.Moore-2@nasa.gov

Over the course of 2009-2010, DEVELOP student research teams carried out two independent research projects focused on the Chesapeake Bay Watershed. The first investigated the threat posed by invasive species to forests in Maryland. The second investigated the detection of winter cover crops throughout the watershed from satellite data.

Introduction

The DEVELOP National Program is an Earth Science research internship, operating under NASA's Applied Sciences Program[1]. Each spring, summer, and fall, DEVELOP interns form teams to investigate Earth Science-related issues. Since the fall of 2003, NASA Goddard Space Flight Center (GSFC) has been home to one of 10 national DEVELOP teams. In past terms, students completed a variety of projects related to the Applied Sciences "Applications of National Priority," such as Public Health, Natural Disasters, Water Resources, and Ecological Forecasting. These projects have focused on areas all over the world, including the U.S., Africa, and Asia. Recently, Goddard DEVELOP students have turned their attention to a local environment—the Chesapeake Bay Watershed.

The Chesapeake Bay Watershed is a complex and diverse ecosystem, spanning approximately 64,000 square miles. The watershed encompasses parts of six states: Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia, as well as the District of Columbia. The bay itself is the biggest estuary in the U.S., with over 100,000 tributaries feeding into it. The ratio of fresh water to salt water varies throughout the bay, allowing for a variety of habitats. The bay's wetlands, marshes, forests, reefs, and rivers support more than 3,600 plant and animal species, including birds, mammals, reptiles, amphibians, fish, and crabs. The bay is also commercially significant. It is ranked third in the nation in fishery catch, and supplies approximately 500 million pounds of seafood annually.

This image shows the outline of the Chesapeake Bay Watershed, the states included in the watershed, and the Chesapeake Bay. **Image credit:** USGS

In addition to its abundant flora and fauna, the Chesapeake Bay Watershed is home to approximately 16.6 million people, who live and work throughout the watershed, and who use its diverse resources for recreational purposes. Over the past several decades, the population throughout the watershed has increased rapidly, resulting in land-use changes, and ultimately decreasing the health of the Chesapeake Bay Watershed. Over the course of 2009-2010, DEVELOP student research teams carried out two independent research projects focused on the Chesapeake Bay Watershed. The first investigated the threat posed by invasive species to forests in Maryland. The second investigated the detection of winter cover crops throughout the watershed from satellite data.

Chesapeake Bay Watershed Invasive Species Forecasting

The United States Department of Agriculture's (USDA) National Invasive Species Information Center (NISIC) defines an *invasive species* as a species that is non-native, or alien, to the ecosystem under consideration, and whose introduction causes, or is likely to cause, economic or environmental harm. Economically, the impact from invasive

[1] To read more about the DEVELOP program, please see *The Earth Observer's* March-April 2010 issue [**Volume 22, Issue 2,** pp.7-9], May-June 2010 issue [**Volume 22, Issue 3,** pp. 11-13], July-August 2010 issue [**Volume 22, Issue 4,** pp. 10-12], September-October issue [**Volume 22, Issue 5,** pp. 10- 12], and November-December 2010 issue [**Volume 22, Issue 6,** pp. 14-19].

species is estimated to be $100–$200 billion per year in the U.S. alone. Environmentally, invasive species often out-compete native plant species, creating a monoculture. Further, invasive monocultures often do not support the same insect and animal populations that the original, native ecosystem supported.

A new invasive species, *Oplismenus hirtellus ssp. undulatifolius,* commonly known as "wavyleaf basketgrass" (WLBG), was first found in Maryland in 1996 in the Patapsco Valley State Park. Since its discovery, WLBG has been recorded growing in coastal plain, piedmont, and montane regions of Maryland. The species does not tolerate direct sunlight, and is found in full canopy forests and shady riparian zones. Soil testing at WLBG invasion sites shows that the species can thrive in a wide range of pH levels.

Overall, WLBG has similar habitat preferences as *Microstegium*—also called "Japanese stiltgrass." This invasive is the most damaging invasive plant in the Mid-Atlantic

[*Left to right*] Close-up of a "wavyleaf basketgrass" plant; "wavyleaf basketgrass" at the site of initial discovery, in 1996; the spread of "wavyleaf basketgrass" through the site of initial discovery, in 2007. **Images from: Kerrie Kyde** [Maryland Department of Natural Resources]

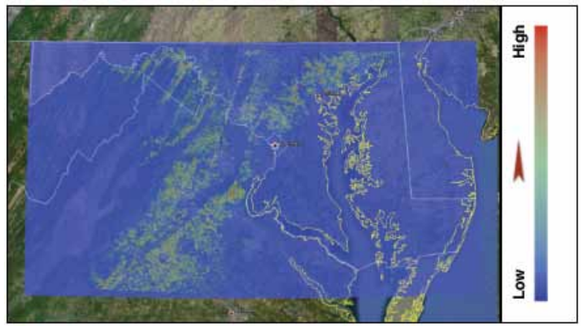
region. It has spread across the entire East Coast since its introduction to the U.S. 100 years ago, outcompeting native vegetation and covering forest floors. WLBG has been found to be considerably more competitive than the Japanese stiltgrass when invading forested areas. A return trip to the site of initial discovery in 2007 revealed that the original 50-ft patches [*see middle image above*] had increased to diameters of up to 500 ft, scattered across more than 1000 acres of forest [*see image on right above*]. It is estimated that this species could invade 10% of the forests in the Eastern U.S. in the next decade.

In response to the threat that WLBG poses on forests throughout the Chesapeake Bay Watershed, the Maryland Department of Natural Resources (MD DNR) approached DEVELOP for assistance in creating a method for early detection and rapid response to WLBG invasions. Students worked with NASA science advisor **John L. Schnase** [GSFC], to identify areas at highest risk of invasion. Schnase, representing NASA's Applied Sciences Program, worked in partnership with the U.S. Geological Survey (USGS), the National Park Service (NPS), the Bureau of Land Management (BLM), and other federal agencies, to develop NASA's Invasive Species Forecasting System (ISFS). The ISFS is an ecological modeling framework that uses remotely sensed environmental predictors in combination with observational data on plant locations, to produce landscape-scale predictive habitat-suitability maps for invasive species of interest.

*In response to the threat that wavyleaf basketgrass (WLBG) poses on forests throughout the Chesapeake Bay Watershed, the Maryland Department of Natural Resources approached DEVELOP for assistance in creating a method for early detection and rapid response to WLBG invasions. Students worked with NASA science advisor **John L. Schnase** [GSFC], to identify areas at highest risk of invasion.*

DEVELOP students acquired a series of NASA satellite images to provide ISFS with the necessary environmental data. A one-year composite image from the Moderate Resolution Imaging Spectroradiometer (MODIS) provided landcover data. Data from the Shuttle Radar Topography Mission (SRTM), which was flown onboard the Space Shuttle *Endeavor* in February 2000, provided elevation data. From these data, slope and aspect layers were created. A series of Normalized Difference Vegetation Index (NDVI) phenology layers were acquired that were derived from MODIS data. These layers included NDVI seasonal variation, NDVI annual maximum, NDVI green-up, and NDVI brown-down. In all, 38 data layers were used as inputs into the model. *In situ* presence and absence points for WLBG were collected from several sources, including MD DNR records, private citizen accounts, and university researchers. DEVELOP students also accompanied the MD DNR on several field excursions to look for the species in local state parks.

The DEVELOP team brought these elements together within the ISFS to produce habitat-suitability maps for the species. Since WLBG has not yet been listed on the national list of invasive species, MD DNR does not have the funds necessary to conduct exhaustive surveys for the species throughout the state. **The predictive habitat-suitability maps produced by the DEVELOP project can greatly enhance the ability of MD DNR to locate and eradicate WLBG from state and private lands, by allowing them to focus survey efforts on areas where the plant is most likely to occur.**

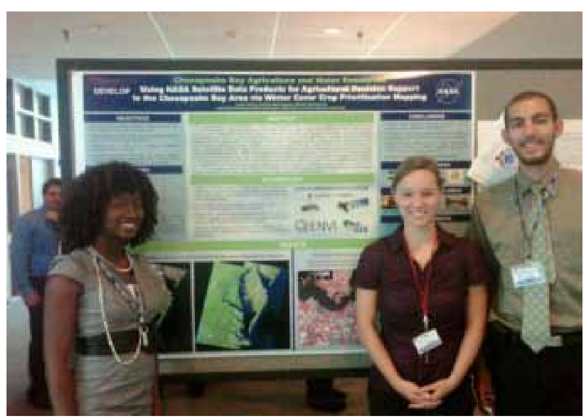


Map of predicted "wavyleaf basketgrass" habitat suitability, produced during the Summer 2010 term showing potential distribution of the species, with high and low habitat suitabilities.

Chesapeake Bay Agriculture and Water Resources

Approximately one quarter of the land in the Chesapeake Bay Watershed is used for agricultural purposes. When planted fields are harvested in the fall, residual nutrients are left behind in the soil. These nutrients may then be washed into local river and stream systems, where they become pollutants that flow into the bay. This process, called *nutrient loading*, has negative impacts on the ecological and economic health of the bay. Agricultural runoff is the largest source of nutrient loading to the bay annually, contributing to harmful algal blooms, submerged aquatic vegetation degradation, fish kills, and decreases in shellfish populations.

To mitigate the effects of agricultural runoff, farmers are encouraged to practice nutrient management during the fall and winter seasons. *Cover crops* are a widely accepted best management practice (BMP), having the ability to use residual nutrients and thus decrease nutrient runoff into the bay. Cover crops are non-harvested, unfertilized, winter cereal-grain crops, such as rye, wheat, and barley. Cover-crop programs vary by state.



Chesapeake Bay Agriculture and Water Resources team members **Melissa Oguamanam** [University of Maryland, College Park], **Lauren Kaiser** [University of Maryland, College Park], and **Andreas Moshogianis** [University of Southern Mississippi/NASA Stennis Space Center] present their research poster at the 2010 Goddard Space Flight Center Summer Intern Poster Session.

Of the states in the Chesapeake Bay Watershed, Maryland has the most extensive and well-funded cover-crop program, with over 1 million acres of cropland suitable for cover crop planting. In 1992, the Maryland Department of Agriculture (MDA) began a four-year incentive program to encourage farmers to adopt cover crops as a BMP for their land. Farmers who adopted this practice were offered $20 per acre planted to offset costs associated with implementation. In 2010, farmers who practice cover crop planting were eligible to receive up to $80 per acre planted with cover crops.

peake Bay Watershed; thus, cover crops are not planted uniformly in all suitable areas. Systematic assessments (e.g., yearly) of cover crops from satellite data are not currently used within the Chesapeake Bay Watershed Modeling System. The analysis of the spatial extent and temporal change of cropland using remotely sensed data is of critical importance to the analysis of nutrient loading to the bay. These data have the potential to not only detect the spatial extent of winter cover crops across the entire watershed, but also to detect change in crop-land area over time, allowing potential users and partners to detect areas where cover crop planting can be beneficial.

The DEVELOP Winter-Cover-Crop team worked in collaboration with NASA science advisor, **Eric Brown de Colstoun** [GSFC] to generate satellite-based leaf-on and leaf-off maps of agricultural lands subject to the Winter-Cover-Crop program in Maryland. The team mosaicked a series of Landsat 5 Thematic Mapper (TM) scenes with coverage of the watershed. The NDVI, an index broadly indicative of canopy greenness, was calculated for each scene to determine the difference between vegetated and non-vegetated regions in the scenes. The scenes were then overlaid with the National Crop Land Dataset, which outlines all land parcels designated as croplands by the USDA. All pixels with an NDVI of 0.3 or greater, which fell within the boundaries of the USDA cropland parcels, were identified. The combined mosaics and NDVI calculations allowed for the creation of a *leaf-off mosaic*—a map delineating areas where winter cover crops are planted and grown. To the team's knowledge, this was the first such map derived from satellite data for this region.

DEVELOP students gain hands on experience with NASA remote-sensing technology, as well as spatial analysis tools, and their application to the investigation of Earth Science issues. Through these projects, students at Goddard were able to gain a new perspective on the Chesapeake Bay Watershed and benefit their local community where they live, learn, and work.

This project demonstrated the potential of Landsat data to identify cover-crop coverage in the Chesapeake Bay Watershed region. The calculated NDVI and the *leaf-off mosaic* generated from Landsat 5 TM offers enhanced detection of winter-cover-crop distribution on agricultural fields that are likely to have high levels of residual nitrates and other nutrients following fall harvests. **The products produced by the team show that remote sensing has the potential to be of great benefit in the ongoing effort to restore the Chesapeake Bay. Decision makers can use these maps to identify high-risk areas of nutrient loading due to lack of cover crops.**

Conclusion

Students gain valuable experience conducting DEVELOP projects, while directly impacting the partners and local communities with which they work. DEVELOP interns have the opportunity to work directly with NASA scientists, who teach them how to conduct applied scientific research and better prepare them for the future. Students gain hands on experience with NASA remote-sensing technology, as well as spatial-analysis tools, and their application to the investigation of Earth Science issues. Through these projects, students at GSFC were able to gain a new perspective on the Chesapeake Bay Watershed and bring benefits to the local community where they live, learn, and work.

For more information, please visit the DEVELOP website at: *develop.larc.nasa.gov.* ■

feature articles

Aura Research Highlights from the Annual Science Team Meetings

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This article presents research highlights from three recent meetings related to Aura.

OMI Science Team Meeting

The 15th annual Aura Ozone Monitoring Instrument (OMI) Science Team Meeting (STM) was held June 15-17, 2010, at the Dutch Royal Meteorological Institute [Koninklijk Nederlands Meteorologisch Instituut (KNMI)] in De Bilt, Netherlands. There were approximately 80 participants with over 60 talks and posters. Current research that was presented contributes to Aura's three main science topics: 1) tropospheric composition and air quality; 2) atmospheric composition and climate; and 3) stratospheric change.

A major topic of the meeting was the success of the OMI Aerosol Index (AI) and sulfur dioxide (SO_2) data for characterizing the plume of the Icelandic Eyjafjallajökull volcano. The data were used by aviation officials to declare "no fly" zones. These data are provided in near real time via the web through a NOAA website. In addition, the Finnish Meteorological Institute (FMI) has recently expanded their suite of very-fast-delivery products over Europe, obtained from the direct broadcast link, to include SO_2 and AI.

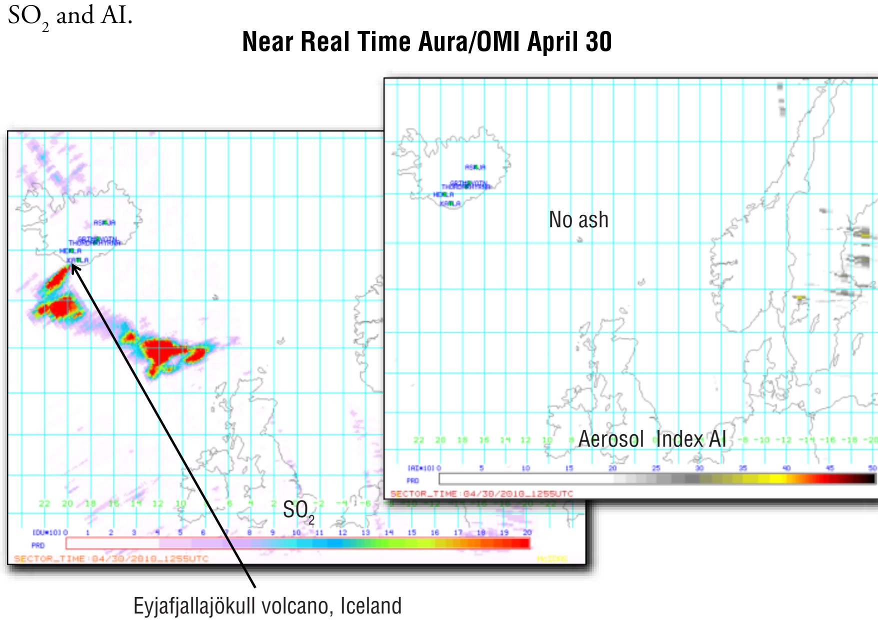

Figure 1. On April 30 the Ozone Monitoring Instrument (OMI) on Aura detected a plume of sulfur dioxide downwind from the Eyjafjallajökull volcano in Iceland [*left*] but did not detect any ash over the region [*right*].

There were several talks on new, improved, and validated OMI data products including ozone profiles, tropospheric ozone, nitrogen dioxide (NO_2), SO_2, bromine monoxide (BrO), formaldehyde (HCHO), and aerosol optical depth retrieved above optically thick clouds. There were two talks related to the analysis of OMI BrO total column data following the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) and Aerosol, Radiation, and Cloud Processes affecting Arctic Climate (ARCPAC) measurement campaigns in which tropospheric BrO was measured. A significant amount of the total column BrO in the Arctic is now understood to be in the stratosphere and free troposphere.

Other presentations highlighted several different applications of OMI data for monitoring air quality. For example, OMI data are used to study interannual differences in aerosols produced from Southern Hemisphere biomass burning. Lifetimes of pollutants such as SO_2 and NO_2 have been calculated with OMI data. NO_2 and other OMI data are also being used to evaluate air-quality models and provide timely top-down data are also being used to evaluate air-quality models and provide timely top-down constraints on emissions. There was also discussion about using OMI HCHO and NO_2 ratios for air quality decision making.

OMI also continues to contribute to derived long-term trends in total ozone. A combined dataset that includes OMI agrees with ground-based data to within 1%. However, a difference in tropical trends has been noted between OMI and Stratospheric Aerosol and Gas Experiment (SAGE) data and is currently under investigation. These data have also been used in a multi-sensor reanalysis to produce a 30-year product. In addition, a global long-term dataset of surface UV has also been produced.

There was also discussion about improvements in flagging of data affected by the so-called OMI row anomaly. This anomaly currently affects about half of the OMI swath. In the past year, the anomaly has been relatively stable. Users are encouraged to work with the OMI data producers in order to ensure that affected data are appropriately screened.

TES Science Team Meeting

An Aura TES STM was held June 16-17, 2010 on campus at the California Institute of Technology in Pasadena, CA. There were more than 30 participants with talks and posters on science applications using TES measurements, improvements in TES retrievals, and discussions of products including ammonia (NH_3), carbon dioxide (CO_2), and ozone outgoing long-wave radiation that are included in the next release of TES data, as well as constituents including methanol (CH_3OH), formic acid (HCOOH), and acetylene (C_2H_2) that are being investigated in TES spectra.

Participants received briefings on the status of TES. The instrument has shown wear consistent with what would be expected after six years of operations. The interferometer control system continues to show signs of wear, and TES operations have been optimized to extend its life. The TES global survey procedure has been modified to reduce the number of times that a ribbon cable is flexed to make measurements of a blackbody from hundreds per global survey to two. Results from this new mode of operations have been tested and retrieved constituents are comparable to those obtained with much more frequent use of the blackbody. While it is known that TES's remaining lifetime is limited, it is not known exactly how long it will last; additional changes in observing pattern may be justified in the future. TES observations of tropospheric composition have applications for air quality and climate. Topics of science presentations included use of carbon monoxide (CO) to evaluate convective transport in assimilation systems, diagnosis of stratosphere/troposphere exchange, chemical sig-

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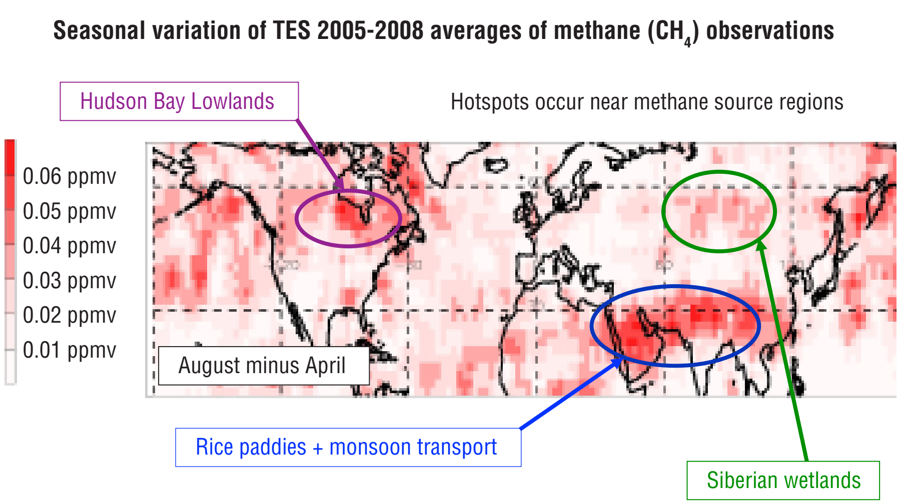


Figure 2. Four years of data (2005–2008) from TES were used to compute the average monthly values of methane concentration (CH_4). To get an idea of seasonal variation the difference between the August average and April average is plotted. Notice that the areas in which the August emissions (averaged from 2005–2008) are greater than the April emissions are located right over the CH_4 source regions. This correlation indicates a link between the emissions and the atmospheric concentrations. A model is being used combined with these data to infer the emissions of CH_4, the second most important anthropogenic greenhouse gas.

natures in boreal forest fires, and use of ozone radiative forcing to reveal biases in climate models.

TES retrievals of both water (H_2O) and deuterated water (HDO) provide information of the hydrological cycle and are useful to understanding tropical tropospheric humidity and the influence of the large-scale circulation on the tropical water distribution. Various techniques are in use to combine TES observations with other measurements to quantify sources of methane and fluxes of CO_2.

Aura STM

The annual Aura STM was held September 27-29, 2010 in Boulder, CO. This was a jam-packed meeting with more than 130 abstracts submitted. The wide variety of topics covered underscored the widespread use of Aura data in atmospheric research. There was a large poster session as well as a full agenda of plenary science talks.

While the "Air Quality" and "Climate" working group meetings were not held at this year's Aura STM (owing to time constraints), there were many oral and poster presentations on these subjects. For instance, several papers described the use of multi-sensor data to characterize the Russian air quality disaster last summer caused when pollution from forest fires accumulated to unhealthful levels. Data from OMI have been shown to be particularly useful for a number of air quality applications—*see* OMI Science Team Meeting summary above. While there were a few presentations on validating the OMI data, most presentations were on the subject of using OMI NO_2, SO_2, and HCHO data to calculate trends and constrain emissions of nitrogen oxides (NO_x), SO_2, and volatile organic compounds (VOCs), respectively. There were also several presentations on poor Chinese air quality, including NO_2 emissions from power plants and the impact of the Beijing Olympic emission controls.

Climate posters focused on a number of topics including improvements in the characterization and estimates of CO_2 from TES, instantaneous tropospheric ozone radiative kernels from TES and their comparison to models, the influence of convection and aerosol pollution on ice cloud particle effective radius, the use of merged upper tropospheric and stratospheric water vapor satellite datasets to assess radiative impacts of water in this region, and studies of the radiative impact of tropical upper tropospheric clouds observed by several A-Train instruments including Aura's Microwave Limb Sounder (MLS).

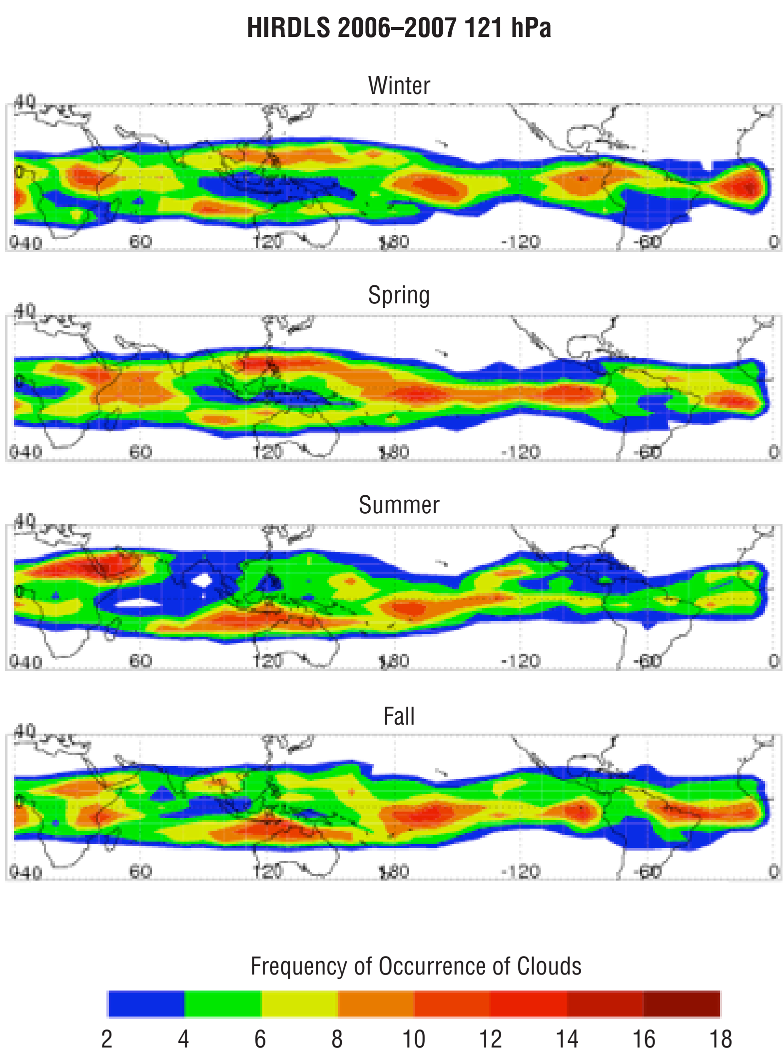


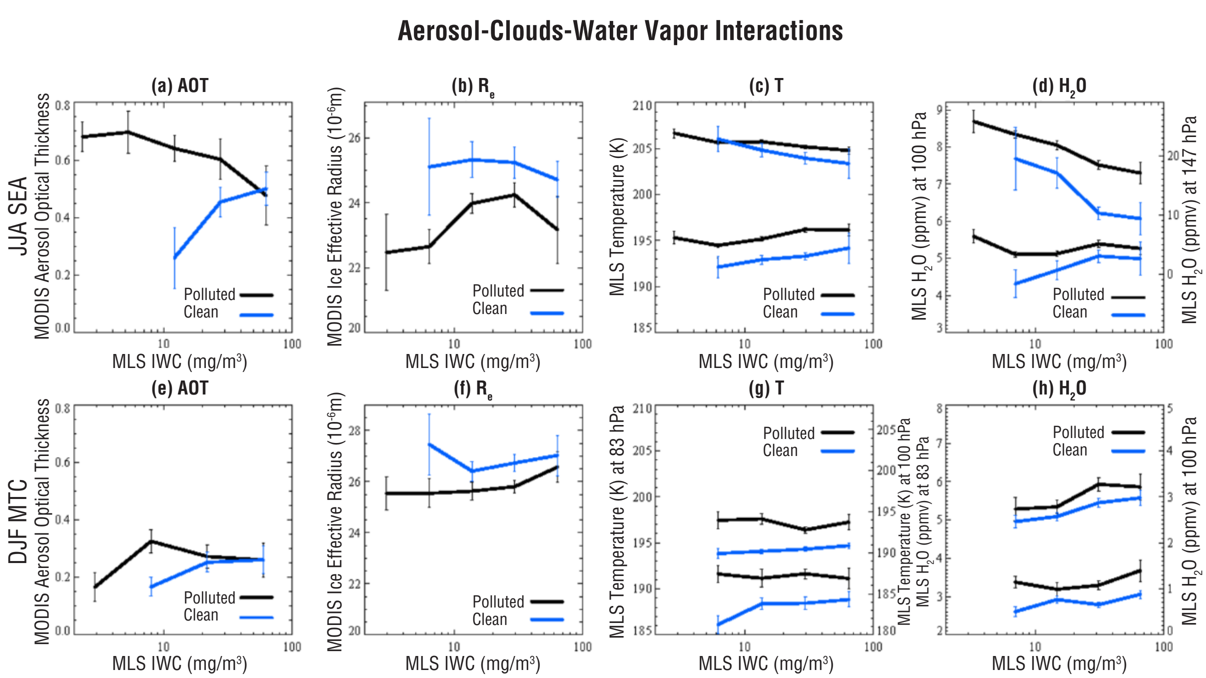
Figure 3. Data from the High Resolution Dynamics Limb Sounder (HIRDLS) show that cirrus clouds of kilometer scale vertical thickness occur more frequently away from the equator than over the equator near Indonesia (around 120°E). This thin cirrus heats the upper troposphere, while thicker cirrus over the equator cools the upper troposphere. The impact of the difference in heating on vertical transport is under investigation.

There were also plenary talks on:

- cirrus heating and cooling rates;
- utilization of Aura and A-Train datasets to evaluate various climate aspects of global models;
- water vapor isotope measurements from TES to evaluate relative humidity in general circulation models;
- uses and validation of TES methane data;
- evidence of aerosol radiative heating as a self-lofting mechanism from the 2009 "Black Saturday" fires in Australia; and
- inverse modeling of CO_2 sources and sinks using satellite and ground-based data.

Observations from Aura instruments have brought new insights into stratospheric chemistry and dynamics. Measurements of long-lived gases including CO, H_2O, N_2O, and O_3 (in the upper troposphere and lower stratosphere) provide new information on middle-atmosphere dynamics, transport, and mixing, as well as the roles of planetary and gravity waves. The ~1-km resolution High Resolution Dynamics Limb Sounder (HIRDLS) profiles provide information about the annual cycle of tropical waves, including Kelvin waves, mixed Rossby-gravity waves, and Equatorial Rossby waves. A novel application compares Kelvin waves derived from HIRDLS data with a global simulation that uses Tropical Rainfall Measuring Mission (TRMM) precipitation observations to force realistic transient waves. Several presentations focused on the composition of the upper troposphere and lower stratosphere and the transport processes that control its seasonal evolution, exploiting the global coverage brought to this region by Aura instruments. MLS upper stratospheric and mesospheric hydroxyl (OH) and nitric acid measurements quantify the response of these species to solar proton events, and the five-year record of OH measurements is being used in conjunction with ground-based measurements and models to assess solar-cycle variability. ■

Figure 4. Measurements from the Microwave Limb Sounder (MLS) have been used to show that pollutants in Asia have a warming and moistening effect on air entering the stratosphere. Over the South and East Asia (SEA) during June-July-August (JJA) and over the maritime continent (MTC) during December-January-February (DJF), the *polluted clouds* (defined by Aura MLS carbon monoxide at 215 hPa > 240 ppbv) have greater aerosol optical thickness (AOT), smaller effective radius (R_e), and higher temperature (T) and water vapor (H_2O) than *clean clouds* (defined by Aura MLS CO at 215 hPa < 100 ppbv) in the tropical tropopause layer.



Taking the A-Train…to New Orleans!

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The A-Train was named with respect to the afternoon equator-crossing time of the original two members of the series, NASA's Earth Observing System (EOS)-era Aqua, launched in 2002, and Aura, launched in 2004.

Some things are just so well-orchestrated that they immediately become classics. Think Billy Strayhorn's jazz standard, *Take the "A" Train,* made famous by Duke Ellington in 1941.

Such is also the case with the constellation of Earth remote-sensing satellites dubbed the *A-Train*. The A-Train was named with respect to the afternoon equator-crossing time of the original two members of the series, NASA's Earth Observing System (EOS)-era Aqua, launched in 2002, and Aura, launched in 2004. The follow-on nature of their orbital tracks was designed to take advantage of synergies in their respective capabilities to focus on aerosols and clouds, and the Earth system's environmental, meteorological, and climatic processes that are affected by these species. The current and planned constellation is shown in **Figure 1**; the individual missions and their instrument manifests are shown in **Table 1**.

Subsequent additions to the suite included CloudSat and the French Centre National d'Études Spatiales (CNES)-sponsored Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), launched together in 2006; Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL)[1], also a CNES contribution, launched in 2004. In sequence, Aqua "leads the train," followed by CloudSat, CALIPSO, and Aura. Future additions include Glory, scheduled for launch in late February 2011, which will be inserted into the space previously occupied by PARASOL (i.e., between CALIPSO and Aura). Further additions include Japan Aerospace Exploration Agency's (JAXA) first Global Change Observation Mission-Water (GCOM-W1), scheduled for launch late 2011–early 2012, and NASA's Orbiting Carbon Observatory (OCO)-2, scheduled for launch in early 2013. Both GCOM-W1 and

…Listen Here, Listen To The Train A Comin'
Hear The Rails A Hummin' (Let's Take A Ride)…
—Billy Strayhorn

[1] **Note**: PARASOL now only occasionally flies coincident with the constellation, having been moved to a lower orbit as of December 2009.

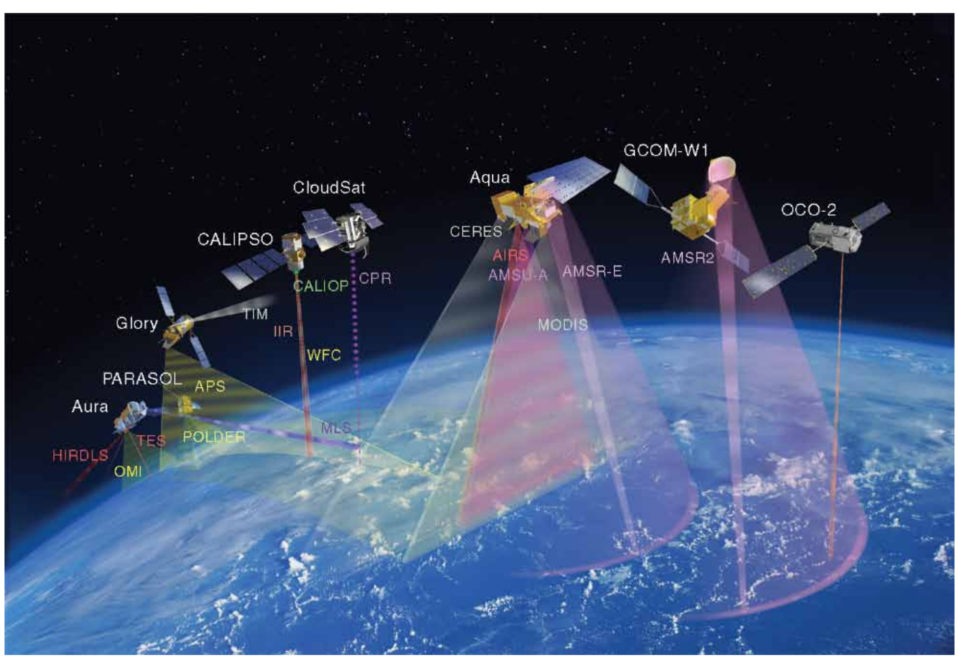


Figure 1. The A-Train constellation, with current and planned (Glory, GCOM-W1, OCO-2) components. The orbital path is from left to right. Instrument scan patterns are shown against the Earth's surface. **Image credit:** NASA

OCO-2 will be placed at the head of the train, i.e., they will precede Aqua in the formation.

Further support for the A-Train is provided by the international organizations shown in **Table 2**.

Table 1. The A-Train Missions and Instruments

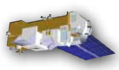
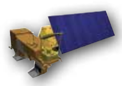
Satellite	Instrument		Measurement
Aura 	HIRDLS	High Resolution Dynamics Limb Sounder	Temperature and composition of the upper troposphere, stratosphere, and mesosphere; aerosol extinction and cloud height
	MLS	Microwave Limb Sounder	Temperature and composition of the upper troposphere and stratosphere; upper tropospheric cloud ice
	OMI	Ozone Monitoring Instrument	Total column ozone, nitrogen dioxide, sulfur dioxide, formaldehyde, bromine monoxide, aerosol absorption, and cloud centroid pressure
	TES	Tropospheric Emission Spectrometer	Temperature, ozone, carbon monoxide, and water vapor profiles from the surface to lower stratosphere
PARASOL 	POLDER	POLarization and Directionality of the Earth's Reflectances	Polarized light measurements of clouds and aerosols
Glory 	APS	Aerosol Polarimetry Sensor	Visible, near-infrared, and short-wave infrared data scattered from aerosols and clouds
	CC	Cloud Camera Sensor Package	Continuous cross-track coverage over a field of view centered on the APS along-track footprint
	TIM	Total Irradiance Monitor	Total solar irradiance with extreme accuracy and precision
CALIPSO 	CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization	High-resolution vertical profiles of aerosols and clouds
	IIR	Imaging Infrared Radiometer	Nadir-viewing, non-scanning imager
	WFC	Wide Field Camera	Fixed, nadir-viewing imager with a single spectral channel covering a portion of the visible (620–670 nm) region of the spectrum to match Band 1 of the MODIS instrument on Aqua

Table 1. The A-Train Missions and Instruments (cont.)

Satellite	Instrument		Measurement
CloudSat 	CPR	Cloud Profiling Radar	Vertical profiles of water amount measured by backscattered radar signals from clouds
Aqua 	AIRS	Atmospheric Infrared Sounder	Highly accurate temperature profiles within the atmosphere
	AMSR-E	Advanced Microwave Scanning Radiometer for Earth Observing System (EOS)	Precipitation rate, cloud water, water vapor, sea-surface winds, sea-surface temperatures, ice, snow, and soil moisture
	AMSU-A	Advanced Microwave Sounding Unit-A	Temperature profiles in the upper atmosphere, especially in the stratosphere
	CERES	Clouds and the Earth's Radiant Energy System	Solar-reflected and Earth-emitted radiation; cloud properties (altitude, thickness, and size of the cloud particles)
	HSB	Humidity Sounder for Brazil	Humidity profiles throughout the atmosphere (inoperative)
	MODIS	MODerate-resolution Imaging Spectroradiometer	Vegetation, land surface cover, ocean chlorophyll fluorescence, cloud and aerosol properties, fire occurrence, land snow cover, and sea ice cover
GCOM-W1 	AMSR2	Advanced Microwave Scanning Radiometer, second generation	Enhanced understanding of water in Earth's climate system and the global water cycle, and of additional components of Earth's climate system and their interactions
OCO-2 	Three high-resolution grating spectrometers		Full-column measurements of CO_2

All told, observations from the currently leading Aqua are separated from the trailing

Aura by about seven minutes, thus ensuring near-simultaneous observations of the same locations below the satellites' tracks.

The A-Train Pulls Into New Orleans… making stops at….

Canal Street…

The first wide forum dedicated to A-Train data, results, and approaches to science was held in Lille, France in October 2007. The focus was to explore synergy among A-Train instruments in acquiring data on aerosols, clouds, precipitation, and radiation. Building on the impacts of that successful meeting, the International Symposium on the A-Train Satellite Constellation 2010, was held this past October in New Orleans, LA. The goal for this meeting was to expand the science focus of the Lille meeting to include broader synergistic and interdisciplinary work, including modeling and data assimilation.

Almost 600 people from international space agencies, academia, and private companies attended the meeting. Held at the Sheraton New Orleans—located at the foot of Canal Street across from the French Quarter—the venue proved large enough and well-located enough that attendees comfortably enjoyed high-tech benefits and southern hospitality. Ninety-five percent of those attending pre-registered, clearly demonstrating the interest and commitment in the community.

A-TRAIN SYMPOSIUM
NEW ORLEANS October 25-28, 2010

And, as discussed below, education was a key feature of the activities.

…the Museum of Natural History…

The Symposium was structured along four themes:

- atmospheric composition and chemistry;
- aerosols, clouds, radiation, and the hydrological cycle;
- atmospheric, oceanic, and terrestrial components of the carbon cycle and ecosystems; and
- weather and other operational applications.[2]

…and Euclid Avenue.

Multiple measurement techniques across the instruments and the slight (but important) differences in view angles, ground swaths, Sun angles, and other geometric and radiometric phenomena that arise from the different instruments and sensor characteristics complicate data synergy and comparisons. These factors are particularly important in data fusion as well as novel approaches to data analysis and visualization, additional foci of the meeting.

Successfully Working the Charts

Jazz musicians are well-known for their improvisation and creativity. And the good ones make it look easy, almost effortless; it is a thing of beauty to behold.

But it is also a bit of an illusion. Any honest musician will tell you that while improvisation may look spontaneous and effortless, it usually only comes about after lots of practice. In jazz, as with any discipline, one can only hope to improvise well after one has become "brilliant in the basics."

Any honest musician will tell you that while improvisation may look spontaneous and effortless, it usually only comes about after lots of practice. In jazz, as with any discipline, one can only hope to improvise well after one has become "brilliant in the basics."

Remote sensing is perhaps more science than art, but the same principles apply. Before improvisation and creativity can emerge, one must become rock-solid with the fundamentals. For remote sensing, these basic structures include theory, data acquisition, analysis, and visualization.

To facilitate and encourage A-Train data use, and to provide the basis for understanding the material to come over the following days, the first day of the Symposium was devoted to data user workshops. These detailed and highly focused sessions were

[2] The host organizing committee consisted of **Chip Trepte** [NASA Langley Research Center (LaRC)], **Hal Maring** [NASA HQ], and **Steve Platnick** [NASA Goddard Space Flight Center (GSFC)]. The international science organizing committee consisted of **Brian Cairns** [NASA Goddard Institute for Space Studies (GISS)], **Anne Douglass** [GSFC], **Keiji Imaoka** [JAXA], **Joanna Joiner** [GSFC], **Michael King** [University of Colorado/Boulder], **Anne Lifermann** [CNES], **Elena Lobl** [University of Alabama/Huntsville], **Norman Loeb** [LaRC], **Hal Maring** [NASA HQ], **Taikan Oki** [University of Tokyo], **Thomas Pagano** [Jet Propulsion Laboratory (JPL)], **Steve Platnick** [GSFC], **Haruhisa Shimoda** [JAXA], **Didier Tanre** [GSFC], **Chip Trepte** [LaRC], and **Deborah Vane** [JPL].

Table 2. Additional International Contributions to the A-Train (see page 12 to complete the list)

Organization	Role(s)
Canadian Space Agency (CSA)	Partner with NASA in CloudSat
Finnish Meteorological Institute (FMI)	Ozone Measuring Instrument (OMI)
National Institute for Space Research (INPE)	Humidity Sounder for Brazil (HSB)
The Netherlands' Agency for Aerospace Programs (NIVR) and Royal Netherlands Meteorological Institute (KNMI)	OMI

conducted by representatives of each of the instrument teams to provide an overview of the measurements and data products, proper and improper uses of the data, known issues, and subtleties associated with their use.

The synergy afforded by the A-Train components has tremendous application across all aspects of Earth system science research and observations. Further, the in-depth involvement of students at all levels has made and continues to make significant contributions to the overall endeavor.

Teams that held workshops represented the Atmospheric Infrared Sounder (AIRS); the Advanced Scanning Microwave Radiometer for EOS (AMSR-E) and the associated AMSR-2 planned for GCOM-W1; the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP), Imaging Infrared Radiometer (IIR), and Wide-field Camera (WFC) combination on CALIPSO; the Clouds and the Earth's Radiant Energy System (CERES), CloudSat, Glory, A-Train data and Goddard Earth Observing System Model, Version 5 (GEOS-5) products; the High-resolution Dynamic Limb Sounder (HIRDLS); the Multiangle Imaging Spectroradiometer (MISR), the Moderate Resolution Imaging Spectroradiometer (MODIS) Aerosol products; MODIS Cloud products; the Microwave Limb Sounder (MLS); Orbiting Carbon Observatory (OCO-2), Ozone Monitoring Instrument (OMI) Trace Gas products; OMI Cloud and Aerosol products; Polarization and Directionality of the Earth's Reflectance (PARASOL); and the Thermal Emission Spectrometer (TES).

The presentations from the user workshops are found online at: *a-train-neworleans2010.larc.nasa.gov/program-events-WS.php.*

Jamming is What It's All About

When performing jazz, creativity and improvisation really begin to emerge when groups of creative individuals come together to create something fresh—this is what makes jazz so distinct. Scientific "jam sessions" over the three days of the Symposium proper provided ample opportunity to share ideas, develop new approaches, and to just generally foster communication between interested parties.

Each day, Tuesday through Thursday, was organized into a morning plenary session with presentations by invited speakers, and afternoons given over to several presentations in each of the four theme areas outlined earlier. While the details are too numerous to include here, short summaries of these plenary presentations are described here. The schedule of presentations and embedded links to the presentations are found at: *a-train-neworleans2010.larc.nasa.gov/program-pm-agendas-listing.php.*

Tuesday, October 26, 2010

Mike Freilich [NASA Headquarters—*Earth Science Division Director*] opened the first plenary session with *NASA's Overview of the A-Train Satellite Constellation*. Freilich discussed the international nature of the constellation, emphasizing the time-phasing of the launches and the longevity of the individual platforms. Explicit in his discussion was the critical need for data continuity within and between A-Train platforms, and with other remote-sensing activities to support high-quality scientific activities. The synergy afforded by the A-Train components has tremendous application across all aspects of Earth system science research and observations. Further, the in-depth involvement of students at all levels has made and continues to make significant contributions to the overall endeavor.

Didier Renaut [CNES] provided an *Overview of A-Train-related French Space Programs and Research.* Renaut discussed the specialization of CNES in its contributions to aerosol, cloud, and radiation programs (*via* PARASOL and CALIPSO); water cycle programs (*via* the Cloud-Aerosol-Water-Radiation Interactions ICARE Thematic Center), and atmospheric composition and greenhouse gas programs (*via* AIRS and the Infrared Atmospheric Sounding Interferometer [IASI] on European Space Agency's Meteorological Operations (METOP) satellite). Data product generation contributions include processing from Level 0 through Level 2 and beyond, and distribution. Tight partnerships within CNES and between CNES and other entities, such as the French National Center for Scientific Research (CNRS) and universities, have been critical to the French contributions in these areas. He emphasized that the depth and breadth of such national cooperation is also a key feature of the international cooperation that is the basis of the A-Train's success.

Haruhisa Shimoda [JAXA and Tokai University] highlighted Japan's contributions to A-Train activities, speaking on behalf of his co-authors, **Keiji Imaoka** and **Keizo Nakagawa**, both from JAXA. After describing current and planned satellites and missions, Shimoda went on to discuss the characteristics and status of AMSR-E on Aqua. His focus was on the instrument's data products and their contributions to understanding phenomena associated with water vapor, sea surface wind speed, sea ice characteristics, and sea surface temperature. Shimoda then provided details of the upcoming GCOM missions that will address aerosol radiative forcing, validating climate models, accurate estimation of primary production, coastal phenomena, and sea ice trends. Further, GCOM will have operational aspects in the areas of numerical weather forecasting, fisheries, navigation, coastal management, crop estimation, forested area coverage, volcano eruptions, and forest fires. Interoperability and data continuity with AMSR-E is a key feature of GCOM-W1 mission planning, *via* synergy and cross calibration.

With the broader brushstroke descriptions of the A-Train and its components having been addressed, **Graeme Stephens** [Colorado State University—*Cloudsat Principal Investigator*] used his slot to address how the A-Train addresses climate imperatives. This began a string of presentations that discussed the data in some detail. Stephen's basic theme was that energy flows in and through the Earth system must be tracked. Stephens provided specific estimates of energy fluxes and very detailed analyses that focused on the lack of understanding in the surface energy balance; planetary imbalance and recent lack of warming; model biases and the impacts of absorbed solar input and bright wet clouds; Arctic sea ice and cloud feedbacks; the discovery of a new class of polar clouds and the effects on Arctic cooling; and aerosol forcing. His presentation reflected the need to develop our understanding of Earth system processes, to test this understanding with predictive models of the system, and to apply these models in projections to guide adaptation and mitigation, all necessary for a 10–30-year window of opportunity considered critical for decision support. There followed detailed description and analysis of observations from A-Train instruments that have already contributed to addressing these requirements, and prioritized recommendations for next steps.

Randall Martin [Dalhousie University and the Harvard-Smithsonian Center for Astrophysics] spoke on behalf of a long list of co-authors and contributors, and provided *Insight from the A-Train into Global Air Quality*. Martin pointed out that there are two key applications of satellite observations for air quality studies: estimating surface concentrations (particularly for large regions for which there are few or no ground-level observations), and top-down constraints on emissions (to improve air quality simulations). Noting that column observations of aerosol and nitrogen dioxide (NO_2) are strongly influenced by boundary layer concentrations, he proceeded to demonstrate the temporal correlation of aerosol optical depth with *in situ* fine particle concentrations (i.e., PM 2.5—particles less than 2.5 micrometers in diameter). A key feature of his analysis was an example intercomparing model results (GEOS-Chem) with vertical profiles from CALIPSO observations, showing a close correlation between the two. Other comparisons between models and observations were provided, resulting in a general approach to estimating surface concentrations, and a method to calculate local sensitivity of changes in trace gas column levels to changes in emissions from the surface. The significant role of chemical transport models and processes was applied to this analysis. He emphasized the roles such analyses have in ecosystem processes generally, and human health, specifically.

Many of the presentations during this portion of the Symposium reflected on the need to develop our understanding of Earth system processes, to test this understanding with predictive models of the system, and to apply these models in projections to guide adaptation and mitigation, all necessary for a 10–30-year window of opportunity considered critical for decision support.

Michael J. Behrenfeld [Oregon State University] described *A Satellite View of Ocean Ecosystems and Carbon*. Behrenfeld discussed the key themes of ocean ecosystem stocks and composition, material flow through ecosystems, ecosystem health, ecosystem change, and events and challenging regions. He then went on to describe how MODIS Aqua is the key tool in this work, with significant support from CALIPSO and PARASOL, and how the work also builds on the heritage provided by the Coastal Zone Color Scanner (CZCS) and the Sea-viewing Wide Field-of-View Scanner (SeaWiFS). Overlap of spectral coverage between CZCS, SeaWiFS, and MODIS is important for data continuity. Such data have clearly shown the linkage between satellite chlorophyll products and changes in the physical environment, from regional to global scales. Process at interfaces—e.g., ocean margins and inland waters—also benefit from satellite observations. New indices, such as the Floating Algal Index, have been developed to monitor unique algal groups and their blooms. Chlorophyll fluorescence provides a unique index for phytoplankton stocks and their physiology—another indicator of ocean

The A-Train platforms and their supporting teams are providing key data and information to support the needs of decision makers as they address the requirements for a sustainable environment and for societal benefits, generally.

ecosystem health—where the dominant physiological signal is iron stress. Another A-Train instrument pressed into service in this area is the CALIPSO lidar (CALIOP), as phytoplankton biomass (carbon) can be linked to the backscatter coefficient. The combination of carbon and chlorophyll data allows assessment of phytoplankton physiological status and global ocean photosynthesis. Also, lidar data may provide an independent "testbed" for inversion results or as a constraint for inversion solutions.

Lars-Peter Riishojgaard [Joint Center for Satellite Data Assimilation (JCSDA)] gave a presentation on *The Role of A-Train Data in Global Numerical Weather Prediction*, and described JCSDA activities, numerical weather prediction (NWP) and societal benefits, the linkage between satellite data and NWP, and how A-Train data contributes to NWP activities. Discussing the application of NWP to such extreme events as the Galveston Hurricane of 1900 and Hurricane Katrina in 2005, Riishojgaard discussed the value of weather forecasting in terms of both human life and economics. He went on to demonstrate how forecasting skill has improved over the past 40 years or so, emphasizing that this skill is due to the availability of satellite observational research-quality data. He also noted that A-Train sensors (i.e., AIRS, MODIS, AMSU-A, and AMSR-E) account for most of the estimated several billion dollars contributed to the U.S. economy by greater skill in NWP. The broad applicability of A-Train data in NWP clearly demonstrates a useful blurring of distinctions between research and operational data. Given the need for global weather prediction, NWP is very much an international activity, with prediction skill routinely analyzed by representatives of the World Meteorological Organization (WMO).

Wednesday, October 27, 2010

Jack Kaye [HQ—*Associate Director of Earth Sciences*] began the day's plenary session with a look *From the A-Train to National Objectives—and Back*. Kaye's presentation described the goals of NASA's Earth Science Program in the national perspective; the role(s) of the A-Train in the integrated NASA Earth Science Research Program; and the future evolution of federal Earth Science research and the implications for NASA. He reviewed the Earth Science Program, with its various international partners, satellite and airborne assets, field campaigns, ground systems, and educational programs, in light of federal and international programs. This review provided the foundation for demonstrating how the A-Train constellation has already made wide and deep contributions to meeting historical and future challenges for Earth System Science. Of particular note was the way that the A-Train platforms and their supporting teams are providing key data and information to support the needs of decision makers as they address the requirements for a sustainable environment and for societal benefits, generally.

Pepijn Veefkind [KNMI] moved the discussion further into scientific specifics. Veefkind spoke on behalf of his nine co-authors, and addressed *A-Train Climate Observations of Trace Gases and Aerosols.* He noted that the Netherlands is extremely sensitive to climate change owing to its low-lying topgraphy. This perspective provides KNMI Earth science researchers with a perspective (and motivation!) that others may not have, particularly as regards atmospheric gas mitigation policies; this perspective also leads to the conclusion that such policies should include gas-aerosol interactions. As an example of such interactions and their effects, Veefkind proceeded to provide an in-depth analysis of the *Black Saturday* fires in Southeast Australia that occurred on February 7, 2009. This event provided an excellent opportunity to use OMI data to examine the effects of absorbing aerosols on atmospheric stability, and to observe the generation and effects of secondary aerosols and their precursors. Bolstered with data from CALIPSO, he and his colleagues were able to explore the processes by which the smoke plume rose to an altitude of 18 km a mere three days after the fires. Meteorological conditions did not favor deep convection, so self-lifting by solar absorption was deemed a plausible explanation, with consequences for aerosol residence times and climatic impacts. Moving on to interactions between trace gases [i.e., formaldehyde, NO_2, and sulfur dioxide (SO_2)], and aerosols, their data demonstrated how the ratio between aerosol optical thickness (AOT) and, trace gases such as NO_2, could be used as a pollution control indicator. Such correlations were found worldwide for both industrial and agricultural activities.

Jean-Jacques Morcrette [European Centre for Medium-range Weather Forecasting (ECMWF)] continued with the aerosol theme. Representing his eight co-authors (all from ECMWF), Morcette discussed the *Use of A-Train Data for Aerosol Validation and Assimilation in the ECMWF Integrated Forecast System.* The thrust of the presentation dealt with modeling and improving regional and limited-area predictive (i.e., forecasting) services, using data from several A-Train components. Such services are provided by a component of Europe's Global Monitoring for Environment and Security (GMES) initiative, with products that address air quality, pollution, biomass burning effects, aerosols, and ultraviolet indices. The forward radiative transfer models used in the analyses take into account several physical processes for 12 aerosol-related prognostic variables, using assimilated observations from MODIS aerosol optical depth data. The application of such models and analyses (which includes data from CALIPSO) were discussed with reference to several events, such as the Saharan dust outbreak of March 2004, fire emissions in August 2007, the Sydney (Australia) dust storm of September 2009, the Eyjafjallajökull volcanic eruption in Iceland in May 2010, and the extensive Russian fires of August 2010. Ground-based Aerosol Robotic Network (AERONET) data are used to verify the results. These 14-day forecasts are now widely used in Europe as boundary conditions for regional and limited-area forecast models, and are being further refined.

Anna M. Michalak [University of Michigan, Ann Arbor/National Center for Atmospheric Research—*Advanced Study Program Faculty Fellow)*] spoke on behalf of 11 additional contributors, and addressed *The C-Train: Highlights of A-Train Contributions to Carbon Cycle Science.* Carbon is found in the atmosphere, the oceans, and terrestrial sinks, with contributions from natural and human processes. The future of natural carbon sinks is a major source of uncertainty for climate prediction, and thus a key goal of carbon cycle science is to reduce these uncertainties. Several current and planned carbon-measuring satellites are being called on to provide data to help in this quest, with particular contributions by A-Train components. For example, global phenology is monitored using vegetation optical depth data from AMSR-E. Data such as these, when combined with global, regional, and site observations and measurements and terrestrial biospheric modeling inputs, support the work of the Multi-scale Synthesis and Terrestrial Model Intercomparison Project to help understand carbon sources and sinks. Additional understanding comes from studies of changes in global forest cover (often due to fires) using MODIS data. The distribution of mid-tropospheric CO_2 from AIRS shows that this species is not well-mixed in the mid-troposphere, and that models don't adequately represent the complexity of CO_2 mixing in the Southern Hemisphere. Detailed structure and abrupt changes are present, and only high-precision space-based data can capture this structure. Future CO_2 data products derived from combining OCO-2, AIRS, and TES retrievals will improve spatial distribution and accuracy of vertical profiles. Overall, A-Train measurements contribute to carbon cycle science with additions to ecosystem structure and dynamics, process understanding and subsequent integration into models, observations of atmospheric carbon-containing gases, and inverse models.

The future of natural carbon sinks is a major source of uncertainty for climate prediction, and thus a key goal of carbon cycle science is to reduce these uncertainties. Several current and planned carbon-measuring satellites are being called on to provide data to help in this quest, with particular contributions by A-Train components.

Norman Loeb [NASA LaRC] led a discussion of the *Influence of Clouds and Aerosols on the Earth's Radiation Budget through Synergistic Use of A-Train Observations*. Using CERES-derived data, Loeb discussed the impact of cloud radiative forcing on general circulation model (GCM)-simulated tropical circulation, namely strengthening some equatorial circulation aspects, and reducing others. Data from CALIPSO, CloudSat, CERES, and MODIS can be combined to give a detailed picture of the vertical distribution of longwave atmospheric heating, demonstrating that the effects of clouds are felt from the marine boundary layer upward. With reference to energy budgets, Loeb showed comparisons between various surface downward longwave flux datasets, with global mean differences as large as 17 W/m^2. A-Train data has also provided the opportunity to study anomaly correlations between products, with general consistency found between CERES fluxes, MODIS cloud anomalies, and AIRS temperature anomalies. The direct, semi-direct, and indirect forcing effects of smoke and aerosols have been examined, showing (for ex-

CALIOP, MODIS, OMI, PARASOL, and CloudSat are all making major contributions to aerosol research, including heretofore unavailable areas of interest, such as nighttime aerosol optical depth over oceans, with no preconceived assumptions about aerosol properties, and the ability to retrieve important parameters simultaneously—something not previously possible.

ample) that scenes darken when absorbing smoke is found over bright clouds, resulting in a net warming. Across the board, data derived primarily from OMI, AMSR-E, AIRS, MODIS, and CERES, are providing unprecedented detail on coupled aerosol–cloud–precipitation–radiative process on short (i.e., interannual) time scales. Such detail is vital to generating and understanding a climate-quality data record, and thus clearly demonstrates the synergy afforded by the A-Train constellation.

Didier Tanre [LOA/CNRS/Université de Lille] (with contributions from 14 colleagues) discussed *Derivation of Aerosol Properties from A-Train Observations*. Noting how the number of yearly publications on aerosol-related topics has been increasing logarithmically since about 1968, Tanre preceded to show how the reported work has increased our understanding of the effects of aerosols on many Earth system phenomena. CALIOP, MODIS, OMI, PARASOL, and CloudSat are all making major contributions to aerosol research, including heretofore unavailable areas of interest, such as nighttime aerosol optical depth over oceans (with no preconceived assumptions about aerosol properties), and the ability to retrieve important parameters simultaneously—something not previously possible. Such work allows observational estimates of direct radiative forcing from aerosols above cloud layers, leading to greater understanding of the effects of ground-level biomass burning (from AIRS and MODIS data), and SO_2 concentrations within the planetary boundary layer due to volcanic eruptions (using OMI and PARASOL data). Three-dimensional representations of aerosol fields have also been greatly improved with such data, and satellite intercomparisons allow for robust tests of retrieval errors or model and/or instrument limits. This work shows that the A-Train constellation has allowed for unanticipated synergy, and supported the development of a new set of algorithms that will combine all relevant measurements within a single inversion algorithm.

Thursday, October 28, 2010

Michael Schulz [Laboratoire des Sciences du Climat et de l'Environnement] provided further examination of the A-Train's roles in aerosol monitoring. With contributions by six colleagues, Schulz described *Monitoring Aerosol Sources, Transport, and Climate Impact Using A-Train Observations and Modeling.* Noting that aerosol radiative forcing is not well understood, he proceeded to address levels of global aerosol optical depth (AOD), the validity of vertical aerosol distribution model results, and regional emissions and trends. Stating that both naturally occurring and anthropogenic aerosols contribute to global mean AOD, Schulz proceeded with a comparative analysis of AOD derived from satellite retrievals and ground-based data, and how *a priori* model assumptions affect model output, often leading to biases. Satellite-based instruments do not necessarily agree about AOD, owing to such factors as lack of dust as derived from MODIS, as compared with PARASOL. For that matter, MODIS on Aqua and Terra do not agree in the global mean, demonstrating the need for improved accuracy. Overall, models must take into account surface emissions, secondary aerosol formation, vertical dispersion and removal, and, therefore, regional climate and aerosol interactions. Without such inputs, models do not accurately match data, although newer models (e.g., new Aerocom Phase II models) are performing quite well over most regions of the Earth's surface, which can show multi-year variations. In addition to those alluded to above, challenges to be addressed include determining the anthropogenic fraction of scattering and absorbing aerosols, absorption above clouds, sampling bias, emission trends, and aerosol-cloud interactions.

Susan E. Strahan [University of Maryland, Baltimore County/GSFC] returned to the theme of atmospheric gases, presenting on *CO in the Upper Troposphere and Lowermost Stratosphere.* Strahan's emphasis was on seasonally varying transport, chemistry and sources, and application of these data to model evaluation. Following a concise tutorial on CO sources, localization, and vertical distribution, she noted that the signal from tropospheric CO is not found above ~20 km. The work described here concluded that several processes affect CO between the surface and the lower stratosphere (LS), including seasonally varying convection and photochemical losses, and quasi-horizontal transport from the upper troposphere to the lowermost stratosphere (LMS). Understanding these processes with respect to CO allows the description of seasonal and spatial variation of transport and chemical processes in the atmospheric regions of interest. The MLS on Aura provides data on structures and cycles, but high biases make it difficult to compare with other levels. Other data sources, such as Measurements on Pollution in the Troposphere (MOPITT) on Terra and AIRS, coupled with potential vorticity from the GEOS data assimilation system, are all combined to give a good picture of CO in the LMS, which differs in the Northern and Southern Hemispheres. Comparison of data with model output shows a similarity of general behavior, but numerical values are not congruent.

Simon Carn [Michigan Technological University] represented work performed by three colleagues, addressing *New Perspectives on Volcanic Clouds from the A-Train*. Comparing volcanic clouds to "dirty thunderstorms," he proceeded to describe the effects of volcanic emissions on the climate system, with effects from stratospheric and tropospheric aerosols on absorption, forward-scattered- and backscattered-radiation, solar heating, effects on clouds, and more. Volcanic clouds are also significant aviation hazards, and ash falls have significant impacts on ground-level phenomena and ecosystems. A-Train constituents, particularly Aura (OMI, TES, and MLS), Aqua (MODIS, AIRS), CloudSat (CPR), and CALIPSO (CALIOP) all have made significant contributions to volcanic cloud studies. A detailed analysis of the generation and movement of volcanic clouds from the Soufrière Hills (Montserrat) eruption in May 2006 and the Eyjafjallajökull eruption in April 2010 (among others) clearly showed how A-Train data are used in analysis of such events, by tracking the clouds' paths and component distribution (e.g., SO_2). Based on such tools, he described a hypothetical A-Train-based eruption monitoring system, noting issues with data latency and spatial coverage gaps.

Eric Vermote [University of Maryland, College Park/GSFC] spoke on behalf of his co-author **Chris Justice** and six contributors about *Monitoring the Land Surface from MODIS: From Science to Applications*. MODIS, on the A-Train's Aqua satellite as well as on NASA's Terra satellite, generates land products that cover a broad range of phenomena over three "suites": energy balance products, vegetation parameters, and land cover/land use. Each land product uses a common surface reflectance product to which an atmospheric correction has been applied. MODIS makes significant contributions to the work of many other programs internationally, and its data are frequently the bases for agricultural and hazard-related decision making and rapid response activities, such as were required during the 2010 Pakistani floods. Near-real-time capabilities that have been developed are major contributors to these capabilities. (There are now over 200 EOS direct-readout ground systems worldwide, covering over 80% of the Earth's land mass.) Of particular significance to the application community is the recent Land Atmosphere Near-Real-Time Capability for EOS (LANCE) effort that provides selected three-hour data from a variety of A-Train sensors (AIRS, AMSR-E, MLS, MODIS, and OMI). The importance of MODIS-based observations and the need for data continuity were key drivers in developing the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project's Visible Infrared Imager Radiometer Suite (VIIRS) and the subsequent Joint Polar Satellite System (JPSS). Such data are basic requirements for both research and operational activities.

MODIS makes significant contributions to the work of many other programs internationally, and its data are frequently the bases for agricultural and hazard-related decision making and rapid response activities, such as were required during the 2010 Pakistani floods.

Hélène Chepfer [Laboratoire Météorologie Dynamique/Institut Pierre Simon Laplace, Université Pierre et Marie Curie, France] spoke on behalf of 11 international contributors, about the *Evaluation of Cloud Description in Climate Models Using A-Train Observations.* Emphasizing that cloud composition and location are key uncertainties for model-based estimates of future climate evolution, Chepfer went on to describe the complementarity of ground- and satellite-based observations in evaluating climate models. A short history of data derived from pre-A-Train satellites placed the role of A-Train data in context, with data from the Earth Radiation Budget Experiment (ERBE), the Scanner for Radiation Budget (ScaRab), CERES, and the International Satellite Cloud Climatology Project (ISCCP) playing major roles. With different cloud types contributing to different top-of-atmosphere (TOA) fluxes, global climate models (GCMs) can produce correct values for the wrong reasons, owing to er-

Table 3: The spectrum of E/PO activities planned around the A-Train symposium

	K-12	Undergraduate/Graduate	Teachers	Public
In-person (at symposium)	*Local student visits to poster session*	Student travel support	1-day teacher workshops (Tues-Thurs)	Lobby exhibit with Dynamic Planet
Direct engagement (outside symposium)	GLOBE Student-Scientist Observation Campaign	*Science Café with A-Train scientist "host"*	Scientist visits to local classrooms (20-30)	*Science Café with A-Train scientist "host"*
Online content	NASA EDGE, near-real-time blog	NASA EDGE	NASA EDGE	NASA EDGE
Media	Local, regional, and national			

The items indicated in *italics* above were planned, but could not be implemented at the Symposium.

ror compensations. Data from the A-Train can address these error compensations via CERES (TOA fluxes), CALIPSO/CloudSat (cloud vertical distribution), PARASOL/MODIS (cloud optical thickness or reflectance), and CALIPSO and others (cloud cover). When used in conjunction with instrument model simulators, such capabilities help ensure that differences between models and observations are due to model deficiencies—key contributions to our understanding of the significant roles that clouds play in climate processes.

Master Classes Can Help, Too

Each day's afternoon sessions were given over to a total of 54 detailed presentations on the four major themes of the symposium, as described earlier. The presentations were chosen to amply reflect the integrative and synergistic applications of A-Train data.

In addition, poster sessions were scheduled for each afternoon, after the workshops. With posters mounted in advance of Tuesday's opening, and made available until late Thursday, there was ample opportunity for symposium attendees to interact "up close and personal" with researchers whose work was spotlighted in this manner. Discussions ranged from the merely interested to the intensely focused.

A complete list of abstracts for the afternoon workshops and the poster sessions is found online at: *a-train-neworleans2010.larc.nasa.gov/program-abstract-listing.php.*

Bringing New Players Along

Jazz musicians are always on the lookout for bright students, as the techniques attendant with coming together in an unplanned fashion to create something new and beautiful need to be communicated to younger players. So, too, is the case with A-Train enthusiasts.

To this end, a multi-faceted education event was planned, based on interest expressed by hotel staff during the initial planning trips. This included a full spectrum of education and public outreach (E/PO) activities, as summarized in **Table 3.**

In some cases, the results of these activities exceeded expectations.

Three on-site teacher workshops were held, reaching a total of 116 teachers including high school, middle school, elementary, and pre-service teachers, as well as teacher educators. The workshops provided an introduction to remote sensing, and tools to enable use of NASA satellite data in the K-12 classroom.

Successful in-person activities included travel support for 48 undergraduate and graduate students to attend. Three on-site teacher workshops were held, reaching a total of 116 teachers including high school, middle school, elementary, and pre-service teachers, as well as teacher educators. The workshops provided an introduction to remote sensing, and tools to enable use of NASA satellite data in the K-12 classroom. While the plan to have local students attend the poster sessions fell through due to overload on their teacher, a number of the workshop attendees did take advantage of the opportunity to learn about cutting-edge science by attending the poster sessions at the end of the workshop day. In addition, an eye-catching lobby exhibit drew in a cross section of the public passing through the busy hotel lobby, and introduced them to the basics of Earth system science and the tools used to conduct such research.

Direct engagement activities included a three-week observation campaign, mediated through an on-line blog (*mynasadata.larc.nasa.gov/elgg*). This experience provided mixed results, with only minimal active participation from the target audience. The experience did, however, provide a number of lessons to be applied to help ensure the success of future attempts. While the *Science Café* did not materialize for a variety of reasons, the scientists' visits to local classrooms on Friday, October 29 exceeded all expectations. Thirteen NASA and university scientists spoke at 29 classrooms in schools around New Orleans, directly impacting over 800 students, teachers, and principals. Two local DEVELOP students affiliated with NASA's Stennis Space Center in Mississippi also visited schools, where presentations about their own recent experiences made a strong impression on students[3].

The NASA EDGE (*www.nasa.gov/nasaedge/*) team attended the Symposium with the goal of sharing parts of the experience with those who could not be there. In addition to a live one-hour webcast on Wednesday afternoon (now available at *www.ustream.tv/recorded/10458577*), they completed a daily highlight video. They also posted a "Best Of" 23-minute video after the event, including some footage from several of the scientist visits to schools. The latter was downloaded over 55,000 times in the first weekend it was posted, providing a large audience a glimpse into this unprecedented cross-disciplinary science event.

With the evident cooperation and enthusiasm that accompanied these E/PO efforts, we hope that this example of interaction with a local community can serve as a model for future NASA science meetings, with tight integration right from the earliest planning stages through final implementation. A notable contributor to the effort's success was identifying and enlisting key local educators, including Jean May-Brett of the Louisiana Department of Education, and Gayle Glusman, former director of the Challenger Center in New Orleans.

Really Good Jazz: Themes and Variations

Across the presentations and posters, several recurring themes arose in regard to the key roles the A-Train is playing in Earth system science. These included:

Scientific benefits, as the A-Train has made significant contributions to numerous multinational studies of the Earth's systems, their individual and interrelated processes, and their responses to change, clearly demonstrating the value of such synergistic satellite constellations.

With a broad range of student-focused programs and many opportunities for students to participate at an active, contributory level, *educational benefits* include a pool of trained candidates to continue climate and Earth system science activities that are already being formed.

Complementarity and synergy are the hallmarks of the international cooperation that underlies the A-Train and its contributions to Earth system science. *Societal benefits* arise because Earth's phenomena pay no attention to borders, and—increasingly—relevant research and operational activities take place without geopolitical bound. Further, given the actual and potential impact of hazards, interfaces between Earth system scientists and those in other disciplines that impinge on human activity—such as social sciences—are increasing in number and range, and are becoming increasingly tight. Science from the A-Train and similar constellations will help inform adapting to and mitigating potential deleterious effects of global change.

Like any good jazz set, the energy and buzz evident during the 2010 New Orleans A-Train Symposium sessions provided ample opportunity for creativity and innovative thinking. By designing a symposium to share information and encourage novel and interdisciplinary studies, it was hoped that ongoing and future A-Train activities will continue to generate new and unique science.

Additional References and Resources for Further Reading

A-Train Homepage *atrain.nasa.gov/*

A-Train Symposium New Orleans 2010
a-train-neworleans2010.larc.nasa.gov/

A-Train Lille 2007
www.colloquium.fr/ei/cm.esp?id=276&pageid=_1ZZ1087LH

DEVELOP Program
develop.larc.nasa.gov/ ■

With a broad range of student-focused programs and many opportunities for students to participate at an active, contributory level, educational benefits include a pool of trained candidates to continue climate and Earth system science activities that are already being formed.

[3] DEVELOP is a NASA Science Mission Directorate Applied Sciences training and development program. Students work on Earth science research projects, mentored by science advisors from NASA and partner agencies, and extend research results to local communities. The latest in a series of articles *The Earth Observer* has run on the DEVELOP Program appears on page 4 of this issue.

NASA/Esri Remote Sensing and GIS Workshop

Stephanie Granger, NASA Jet Propulsion Laboratory, stephanie.l.granger@jpl.nasa.gov

Fifty Earth and remote sensing (RS) scientists and Geographic Information Systems (GIS) experts attended a joint NASA/Environmental Systems Research Institute (Esri) workshop entitled *Bridging the Gap Between Remote Sensing and GIS* November 17–18, 2010. The workshop was held at the Esri headquarters in Redlands, CA. The purpose of the workshop was to bring together a diverse community of experts to explore benefits and barriers of using GIS for Earth Science and applications, with an emphasis on integration of remote-sensing data into GIS.

Remote sensing represents an ever-expanding source of scientific data about our planet. Some individual NASA Earth missions alone provide over a Terabyte (Tb) of data per day. Scientific RS data can help solve problems in diverse applications, including disaster response, environmental planning, global change prediction and remediation, insurance, and private investment. These data attain their greatest value when combined with other data from a variety of sources, yet this seemingly simple step is often very challenging.

GIS has traditionally provided effective technological solutions to the integration, visualization, and analysis of heterogeneous, geo-referenced data, and in some application areas, RS and GIS work together quite effectively. In the sciences, there has been much less communication between the RS and GIS communities, creating inconsistencies in data models, formats, standards, tools, services, and terminology. This workshop was inspired by the need to resolve these technological gaps.

The goals of the workshop were to identify, understand, and help overcome barriers such as:

- Access to scientific RS data by GIS users.
- GIS tools that are unfamiliar to the science community.
- Lack of integration of RS and GIS data and tools.
- Lack of communication between RS and GIS practitioners, particularly for science applications.
- Insufficient reach of scientific RS data to broader user communities, such as for decision support.

Workshop outputs were: 1) identification of the gaps that inhibit RS and GIS integration for science applications; 2) specific recommendations and actions to bridge the gaps; 3) topics for follow-up RS and GIS workshops; 4) a post-meeting *white paper* detailing the current state of RS and GIS integration in the sciences, including barriers and solution strategies; 5) a science-based GIS and RS Esri community; and 6) a "User Group" list of desired enhancements for GIS software for RS and science.

The format of the workshop included a mix of plenary talks and panels, and breakout groups focused on science-themed challenges and technological solutions. Plenary speakers included **Jack Dangermond** [Esri—*President*]; **Diane Evans** [Jet Propulsion Laboratory (JPL)—*Director for Earth Science and Technology*]; **Lawrie Jordan** [Esri]; former Wyoming Governor **Jim Geringer** [Esri—*Director of Policy and Public Sector Strategies*]; **Dan Walker** [Computer Sciences Corporation (CSC)—*Chief Climate Scientist*]; **Semeon Sertsu** [National/Naval Ice Center—*Director of Information Technology*]; and **Jason Hyon** [JPL Earth Science and Technology Directorate—*Chief Technologist*].

The science-themed breakout groups covered six scientific domains: water and energy cycles; oceans and coastal; carbon; land use; ecosystems; and disasters. The science-themed groups were asked to address the GIS and RS needs from the perspective of their science and application communities. Each of the six science breakout groups was asked to address the same four questions:

1. What are the problems that require connecting RS and GIS?
2. What are the key gaps or barriers to the successful use of RS data by GIS?
3. What are the benefits to your communities of combining RS and GIS?
4. What are the most promising ways to bridge these gaps?

Technology-themed breakout groups addressed the GIS and RS challenges raised by the science breakouts to identify technology solutions. Each of the eight technology breakout groups was asked to address the same four questions in development of their technology solution:

1. What are the technological capabilities for combining RS and GIS?
2. What recommendations can you give for bridging the gaps?
3. Who is best positioned to initiate the needed steps?
4. What are the difficulties in implementing these recommendations?

A *wiki* (*oodt.jpl.nasa.gov/wiki/display/Esri*) was established to capture the results of the workshop and breakout group reports. A final report will be uploaded to the wiki in early January. A post-workshop *white paper* expanding on the workshop findings and recommendations will be produced in the near future. ■

NOAA AIRS Team Members Honored with NASA Group Achievement Award

The National Oceanic and Atmospheric Administration (NOAA) Atmospheric Infrared Sounder (AIRS) team members were recently recognized for their outstanding contributions in improving weather forecasting using data from the AIRS and production of its key climate data products. The award ceremony took place at the NASA Sounding Science Team Meeting in Greenbelt, MD last November—see report on page 26 of this issue.

NOAA team members were recognized for running the Jet Propulsion Laboratory (JPL)-developed AIRS Team algorithms on their operational production system and distributing the data to National Weather Prediction (NWP) centers worldwide. They also support algorithm development of the AIRS geophysical products and have helped validate the AIRS data products with their extensive database of *in situ* observations.

NOAA routinely communicates the value of AIRS carbon monoxide, ozone, carbon dioxide, and methane products to their operational users. The NOAA AIRS Team's performance has been outstanding because they have not only provided the global user community with the data in an extremely timely fashion (near real time), they have gone the next step and shown them both how to use it and how accurate it is.

To read the full release and view more images of the award ceremony, please visit: *airs.jpl.nasa.gov/news_archive/2010-12-07-NOAA-Awards/*.

NOAA AIRS Team Members with **Jack Kaye** [NASA Headquarters—*Earth Science Division Associate Director*] [*front row, far right*], **Tom Pagano** [JPL—*AIRS Project Manager*] [*back row, second to right*], and **Moustafa Chahine** [JPL—*AIRS Science Team Leader*] [*back row, far right*].

The NASA Sounder Science Team Meeting Summary

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The NASA Sounder Science Team meeting took place November 1-5, 2010, in Greenbelt, MD. Over 180 people registered for this meeting and over 60 presentations were made in the areas of weather, climate, composition, retrieval methods, and calibration. The meeting addressed the current major operational atmospheric sounders—the Atmospheric Infrared Sounder (AIRS) and Advanced Microwave Sounding Unit (AMSU) on Aqua, and the Infrared Atmospheric Sounding Interferometer (IASI) on the European Space Agency's Meteorological Satellite (METOP)—as well as those planned for the future—the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) planned for the Joint Polar Satellite System (JPSS) and its precursor the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project [NPP].

Session 1: Status and Introduction

Mous Chahine [NASA/Jet Propulsion Laboratory (JPL)—*AIRS Science Team Leader*] opened the Fall 2010 meeting with a welcome and introduction to all participants. Chahine was pleased with the technical and scientific achievements to date and foresees significant climate related science in the future. He was especially pleased with the large and growing community of AIRS data users.

Mitch Goldberg [National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite Data and Information Service (NESDIS)/Center for Satellite Applications and Research (STAR)] described achievements in hyperspectral applications over the last 20 years covering instruments, algorithms, products, research, and science in the U.S. and by our world partners. Goldberg reviewed NOAA's past accomplishments and current weather and climate related work.

Tom Pagano [JPL—*AIRS Project Manager*] presented the AIRS Project status on operations, science data provided, characterization of greenhouse gases with AIRS, the AIRS electronic library, the calibration status of AIRS, and the status of *Version 6* software development. Pagano also presented the tentative recommendations of the NASA Science Community Workshop on Polar Orbiting Infrared and Microwave Sounders held just prior to this meeting on November 1-2, 2010.

Session 2: Water Vapor and Temperature

Joao Teixeira [JPL] presented work on AIRS sounding of the trade wind planetary boundary layer (PBL). AIRS data from the support product was shown to be able to provide realistic information on vertical atmospheric structure. A global and continuous boundary layer height climatology from space has been determined for the first time. There remains potential to extract much more boundary layer information from infrared and microwave sounders.

Brian Kahn [JPL] presented work on the scale dependence of temperature and water vapor variance, using AIRS data, climate models, data assimilation, cloud resolving models, and aircraft observations. Results of AIRS data vs. models show that all models have scaling exponents that are too steep, and cannot observe scale breaks below (AIRS and other sounders' spatial resolutions).

Stephen D. Eckermann [NRL] presented work on stratospheric gravity wave dynamics in the Southern Hemisphere derived from AIRS radiances. Nitrogen-containing *polar stratospheric clouds* around Antarctica are triggered by stratospheric mountain waves. Further, the planetary "hot spots" in gravity wave activity are over the Southern Andes, Drake Passage, and Antarctic Peninsula during the Austral winter. Mountain waves create conditions for formation of nitric acid trihydrate particles in polar stratospheric clouds. These clouds are critical for stratospheric denitrification and late-season ozone loss.

Xu Liu [NASA Langley Research Center (LaRC)] presented work on remote sensing of atmospheric and surface properties from hyperspectral sounders. An approximately 100 super-channel principal component (PC)-based radiative transfer model analysis approach is used that includes clouds and surface emissivity. An eigenvector methodology was developed for this approach. A comparison of the (PC)-based radiative transfer model with the line-by-line radiative transfer model for temperature and water vapor with European Centre for Medium-Range Weather Forecasting (ECMWF) and with radiosondes was shown. The result was used to simulate expected Climate Absolute Radiance and Refractivity Observatory (CLARREO) spectral data. Further work to derive climate datasets from AIRS, IASI, CrIS, and CLARREO instruments using the same methodology is planned.

Julie Wallace [McMaster University] presented work on the effects of temperature inversions on airway disease using AIRS data. Patients' neutrophils, macrophages, and white blood cells were examined at the Firestone Institute of Respiratory Health (Canada). Macrophages and neutrophils increased on AIRS-detected inversion days in chronic obstructive pulmonary disease (COPD) and asthma patients' blood. A cellular correlation with temperature inversions was identified for the first time. Wallace recommends that the occurrence of temperature inversions should be added to air quality forecasts and air quality health indices.

Hengchun Ye [California State University, Los Angeles/JPL] reported on the atmospheric moisture content associated with surface air temperatures over Northern Eurasia. The Clausius–Clapeyron (CC) relationship at constant relative humidity (7%/°C) was found insufficient to explain changes in water vapor with temperature. Observations follow CC theory only under coldest conditions over Northern Eurasia. Other seasons show significant deviations from the CC relationship.

Session 3: Clouds and Dust

JingFeng Huang [University of Maryland Baltimore Country, Goddard Earth Sciences and Technology Center (UMBC)] reported on African dust outbreaks, with a satellite perspective of temporal and spatial variability over the tropical Atlantic Ocean. Extreme African dust outbreak days occurred almost once a week on average. Some outbreaks travel on winds across the Southern U.S. and into the Southwestern U.S. In boreal spring and winter, dust outbreaks shift southward to reach the northeast coast of South America. Dust layer heights are consistent with the dry and warm layers identified from the water vapor and temperature profiles of AIRS—i.e., found mainly in the lower troposphere.

Mark Zondlo [Princeton University] reported on comparisons of ice supersaturated regions of the atmosphere using AIRS and *in situ* measurements on the National Science Foundation (NSF) *Gulfstream V* aircraft. The 1854 nm fiberized Vertical Cavity Surface Emitting Laser (VCSEL) hygrometer is an open-path, fast sensor which avoids common water vapor sampling artifacts. They used the All START08/HIPPO[1] data for AIRS/AMSU–A/VCSEL comparison. The results show very good agreement between AIRS and VCSEL measurements. At cloud scales, the inhomogeneity in the water vapor field—not temperature—is the dominant contribution (~90%) for ice supersaturation and more generally for all relative humidity fluctuations at temperatures less than -40° C. This finding needs to be accounted for in cloud models.

[1] Stratosphere-Troposphere Analyses of Regional Transport/High-performance Instrumented Airborne Platform for Environmental Research (HIAPER) Pole-to-Pole Observations [HIPPO]

Craig Bensen [NASA Goddard Space Flight Center (GSFC)] reports on the minimization of cirrus cloud interference in the detection of ice polar stratospheric clouds with AIRS data assimilation. The technique is useful for generating climatologies, following individual clouds, or determining cloud size, and can enhance our understanding of polar stratospheric cloud dynamics.

Session 4: Weather Forecasting Improvements

Chris Barnet [NOAA/NESDIS/STAR] reported on sounding science progress at NOAA. They migrated the AIRS Science Team algorithms to NOAA's operational IASI/AMSU/Microwave Humidity Sounder (MHS) systems and they have an operational commitment to migrate AIRS/IASI code for use on the CrIS/ATMS instruments planned for NPP and JPSS. They also are assuming responsibility for calibration and validation of the operational Northrop Grumman Aerospace Systems (NGAS) Level-2 Environmental Data Record algorithm.

Stephen English [U.K. Meteorological Office] presented plans and preparation for satellite sounders under the Met Office, ECMWF, Centro de Previsão de Tempo e Estudos Climáticos (CPTEC), and the NPP Satellite Application Facility for Numerical Weather Prediction (NWP-SAF). Current use of NPP-like instruments [i.e., AIRS, IASI, AMSU, MHS, Special Sensor Microwave Imager/Sounder (SSMIS)] at NWP-SAF requires that preparation be made at numerical weather prediction (NWP) Centres and that a strategy be developed for NPP instruments at each location (i.e., Met Office, ECMWF, CPTEC). Part of that preparation is the development of principal component (PC) analysis to compress the emissivity spectrum. Data is increasingly used in the presence of clouds, and over land surfaces and sea ice. Further, the entire spectral range is increasingly used for trace gases and PC analysis. Numerical Weather Prediction systems provide excellent tools to test instrument impact/monitor instrument performance and provide a necessary input for all calibration/validation activities.

Brad Zavosky [NASA Short-Term Prediction And Research Transition (SPoRT)] presented regional data assimilation and modeling activities with Hyperspectral Sounder Profiles at the SPoRT center. Severe storm forecasts of convective precipitation in Eastern Texas show marked improvement using AIRS data. Control produces some rain but no significant precipitation. With AIRS data a more realistic convective precipitation line is predicted. A new hardware device, SPoRT *Weather in a Box*, is a desktop supercomputer that is envisioned to take SPoRT activities beyond sensitivity studies in the use of hyperspectral sounder profile data.

Oreste Reale [UMBC] presented improved AIRS-based forecasts of flood-producing precipitation, and the global impact of clear-sky radiances versus quality-controlled cloudy retrievals. In addition to improved global skill scores, AIRS affects the depiction of tropical weather systems. Specifically, significant forecast track improvements for Tropical Cyclone Nargis (2008) occurred when quality-controlled AIRS cloudy retrieval assimilations were used. AIRS quality-controlled cloudy retrievals also positively impact Extra Tropical Transitions. The importance of not rejecting AIRS-derived information from cloudy areas becomes even more evident with this work.

Hui Liu [National Center for Atmospheric Research (NCAR)] reported on improving forecasts of tropical cyclone (TC) intensity and track using AIRS water vapor (Q) observations with an ensemble data assimilation system. Ensemble data assimilation is used for TC forecasting. A control run is first made that assimilates radiosonde, cloud winds, aircraft data, and surface pressure data. Next an AIRS Q run is made that is the same as the control run but adds in AIRS Q soundings. The results suggest that through the advanced ensemble data assimilation technique, AIRS Q data improves water vapor, temperature, and wind analyses in a TC environment.

Session 5: Carbon Monoxide & Methane

Juying Warner [UMBC] reported on the AIRS carbon monoxide (CO) update and validation of *Version 6 (V6)*-vs. *Version 5*+ software. The validation observations are from the following field campaigns: NASA Intercontinental Chemical Transport Experiment (INTEX)-A, B; Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS); and the High-performance Instrumented Airborne Platform (HIAPER) (aircraft) Pole-to-Pole Observations [HIPPO]. It also uses ground measurements from NOAA's Earth Systems Research Laboratory Global Monitoring Division (GMD) and the Network for the Detection of Atmospheric Composition Change (NDACC) using Measurement of OZone and water vapour by AIrbus in-service airCraft (MOZAIC) and Japanese Airliners for data sources. When using dynamic CO fields, zonal-mean or three-dimensional, more realistic values are obtained especially in the lower troposphere in the Northern and Southern Hemisphere. Validation and testing for AIRS *V6* CO and O_3 software will continue with more complete collections of *in situ* measurements.

Monika Kopacz [Princeton University] reported on global estimates of CO sources with high resolution by adjoint inversion of multiple satellite datasets, specifically: Measurements of Pollution in the Troposphere (MOPITT) on Terra; AIRS on Aqua; the SCanning Imaging Absorption SpectroMeter for Atmospheric CartograpHY (SCIAMACHY) on ESA's Envisat; and the Tropospheric Emission Spectrometer (TES) on Aura. The Goddard Earth Observing System's Chemical Transport Model (GEOS-Chem) was used as the comparison platform. This work gave a global annual CO emission of 1350 Tg. It also shows regional satellite inconsistencies in the Southern Hemisphere that result in overestimated sources. This should provide motivation for acquiring more accurate data.

Leonid Yurganov [UMBC] reported on CO from the Russian fires of 2010 observed by AIRS, MOPITT, and ground-based instruments. AIRS and MOPITT track CO from forest fires perfectly. However, both underestimate CO from forest fires in the boundary layer. Retrievals from ground-based spectrometers depend just slightly on *a priori* data and demonstrate 2–3 times higher CO total columns than AIRS and MOPITT. Corrections in AIRS and MOPITT data are expected to change estimates of CO emission dramatically.

Lesley Ott [GSFC] reported on CO emissions and transport from the 2010 Russian fires, with a modeling study using the GEOS-5 analysis system and AIRS. The GEOS-5 CO models—including emissions from fossil and biofuels that are generated from hydrocarbons (e.g., methanol, isoprene, methane, terpenes)—was used. Modeled emissions are distributed throughout the Planetary Boundary Layer (PBL). Horizontal variability of CO matches the AIRS observations well. However, the average over the Moscow region indicates that GEOS-5 is biased high by ~25 ppbv. In comparison with AIRS CO observations, the model reveals high bias in background CO mixing ratios over Europe and also reveals low bias in CO mixing ratios during peak fire activity.

Xiaozhen (Shawn) Xiong [NOAA/NESDIS/STAR] reported on seven years of methane (CH_4) observations from AIRS and some comparisons between NOAA IASI and AIRS CH_4 products. Xiong reports that the summer increase of mid-upper tropospheric CH_4, and the seasonal cycle is nearly opposite to the summer minimum of CH_4, in the marine boundary layer. By some criteria, IASI has better channels than AIRS for CH_4 retrievals, but the accuracies for both instruments are similar. Another result is that CH_4 from AIRS vs. the Japanese Greenhouse Gases Observing Satellite (GOSAT) (which measures total column CH_4) are in good agreement. The total column amounts of CH_4 from AIRS agree well with GOSAT measurements in the near infrared, suggesting an increased utility of AIRS in estimating surface sources.

Elana Fertig [University of Maryland, College Park (UMCP)] reported on assimilating satellite radiance observations with a local ensemble Kalman filter. Ensemble-based assimilation schemes utilize flow-dependent forecast uncertainties and provide superior estimates compared to operational schemes because they account for *errors of the day*. Assimilating satellite radiance observations improve forecasts of temperature and winds with this technique.

Session 6: Carbon Dioxide

Eugenia Kalnay [UMCP] reported on the assimilation of AIRS carbon dioxide (CO_2) observations with an Ensemble Kalman Filter in a Carbon Climate model. Different CO_2 vertical gradients give different CO_2 fluxes. Assimilating CO_2 adjusts CO_2 vertical gradients and requires observations in the lower troposphere to further constrain the gradients. Assimilating CO_2 improves spatial patterns seen in data and also improves surface seasonal cycle and the north-south gradient.

Baijun Tian [JPL] reported on tropical mid-tropospheric CO_2 variability driven by the Madden-Julian Oscillation (MJO). The MJO is characterized by slow eastward-propagating oscillations in equatorial deep convection and baroclinic large-scale circulation. The MJO impact on weather is documented and well understood. A clear MJO signal exists in the AIRS CO_2 data with a magnitude of ±0.7 ppmv. The MJO CO_2 signal appears to be driven by the lower-tropospheric large-scale vertical motions associated with the MJO. These findings are consistent with higher CO_2 values at the surface than in the upper-troposphere.

Edward Olsen [JPL] reported on the AIRS mid-tropospheric CO_2 product. The AIRS data show CO_2 is not well mixed in the mid-troposphere with a seasonally-variable belt of enhanced CO_2 in the Southern Hemisphere. Complex Southern Hemisphere CO_2 dynamics and a connection between the Northern Hemisphere and Southern Hemisphere are also shown. A University of Hawaii/JPL study finds influences of El Niño in mid-tropospheric CO_2 levels are observed by AIRS that agrees with a Walker Circulation model. Continuing validation and comparisons with *in situ* measurements are needed. Olsen showed a monthly global climatology of mid-tropospheric CO_2.

David Baker [Colorado State University Cooperative Institute for Research in the Atmosphere (CIRA)] reported on a comparison of AIRS and GOSAT CO_2 retrievals to GEOS-5 modeled fields at ~50 km resolution. Measuring CO_2 from satellites provides enough spatial/temporal coverage to pin down regional carbon sources/sinks and provide insight into dominant processes in the global carbon cycle. When assimilating satellite data, systematic errors need to be identified and removed. Biases must be reduced down to < 0.5 ppm and random errors to < 2 ppm levels. Comparing the retrievals to a good forward model—e.g., GEOS-5-driven off-line with the Parameterized Chemical Transport Model (PCTM) transport model and run from 1992–2010—shows that realistic gradients are developed within the stratosphere.

Alexander Ruzmaikin [JPL] reported on patterns of CO_2 variability from AIRS data. The AIRS observations provide an almost 8-year-long global CO_2 concentration record in the mid-troposphere. However, the AIRS CO_2 distribution is not reproduced by models, so pattern recognition techniques must be applied to the data. Spatial and temporal patterns of AIRS data are evaluated using PC Analysis with resultant empirical orthogonal functions (EOF) used in this investigation. The first EOF explains more than 92% of variance and trend, while the second EOF shows annual and semi-annual variability, and the third EOF shows a pattern in the Southern Hemisphere.

Andrew Tangborn [GSFC/UMBC] reported on assimilation of AIRS CO_2 into GEOS-5. The work is used to define the impact of assimilating AIRS retrievals. Tangborn concludes that tuning of model background errors indicate an error standard deviation of about 0.1% of the CO_2 mixing ratio. Comparisons with Climate Monitoring & Diagnostics Laboratory (CMDL) surface data indicate that assimilation of AIRS CO_2 into the GEOS-5 improves the accuracy of model surface values of CO_2. Differences between GEOS-5 and AIRS CO_2 can be parameterized by hemisphere, with a systematic negative bias in the model during winter.

Larrabee Strow [UMBC] reported on the retrieval of CO_2 using AIRS. AIRS CO_2 shows more variability than the NOAA *in situ* monitoring system known as *CarbonTracker*. Patterns of AIRS CO_2 observations during the fall season are seen in the Eastern U.S. and Europe. The hyperspectral IR radiances are providing information that is not in the models. CO_2 features appear reasonable, but show more contrast than models that use hyperspectral IR in conjunction with the GOSAT and the Orbiting Carbon Observatory (OCO) instrument's "expected data." He concludes that a combination of assimilated data for meteorological profiles and simple retrievals for minor constituents using surface affected channels is useful.

Session 7: Data Services

Steve Friedman [JPL] reported on *V6* software providing summary status and schedule, with a planned release in Spring 2011. Level 1B software will remain unchanged. The Level 1C radiance product, an improved version of the Level 1B, is expected to be released after *V6*. Level 2 software efforts since the last Science Team Meeting have incorporated/tested new start-up states, retrained regression over longer periods and incorporated a new Radiative Transfer Algorithm (RTA) into the retrieval and has mitigated the loss of AMSU-A Channel 5. Level 3 software will be designed and coded during Level 2 testing. A schedule for *V6* activities was presented.

Bruce Vollmer [GSFC] reported on AIRS Data and Services at the Goddard Earth Sciences Data and Information Services Center (GES DISC). AIRS Data holdings and AIRS data distribution metrics were reported, and ongoing support and recent enhancements were described. The total volume of AIRS data as of this writing is 128 TB, in 10.7 million granules. The data is distributed to over 2000 network addresses. Total transferred volume decreased by 10% over last year, less Level 1A data was distributed, the number of granules accessed grew by 70%, and significantly more Level 2 data was accessed (42% of the total). AIRS Data Services implemented the *Mirador* Search Interface, Level 1B channel subsetting, and Level 2 parameter subsetting. The center also implemented format conversion to *netCDF* [from Hiearchical Data Format for EOS (HDF-EOS) 2] and has *Giovanni* (for AIRS Level 3) available for use. The center has Open-source Project for a Network Data Access Protocol (OpenDAP) for AIRS and a near-real-time data capability. The center also has recently implemented *Pomegranate,* a high-concurrency, high-throughput, and low-latency data service.

Christopher Lynnes [GSFC] reported on a data quality screening service for remote-sensing data. The Data Quality Screening System (DQSS) will provide an easy-to-use service with the expected result of more attention to quality on users' part, with a more accurate handling of quality information and with less user effort. The DQSS is operational for AIRS Level 2 Standard Products, available through the *Mirador* interface at the GES-DISC.

Sharon Ray [JPL] reported on the AIRS Education & Public Outreach status. A new AIRS web site was launched on September 13, 2010, and has had about 3700 visits per month. There are also ~2600 blogs that discuss data/products and/or refer to AIRS in general. Hurricane coverage continues to be a "hot topic," with AIRS providing near-real-time images. An updated NASA *Water Cycle Fact Sheet* also features AIRS. New "hi-definition" series datasets for the large *Dynamic Planet* and *Science on a Sphere* global dataset projection systems have also been released. AIRS is featured in a *Society of Photo-Optical Instrumentation Engineers (SPIE)* story on forecast prediction and, a new AIRS-based visualization of Polar CO_2 is under development.

Session 8: Surface Properties

Glynn Hulley [JPL] reported on improving AIRS surface retrievals using the Moderate Resolution Imaging Spectroradiometer (MODIS) baseline-fit emissivity database. Currently it is very difficult to validate coarse resolution sounder products (e.g., AIRS, IASI), since they exhibit high variability in Land Surface Temperature (LST), particularly during the daytime. Large thermally homogeneous areas are required for good LST measurements and large compositionally homogeneous areas are required for emissivity determination. To remedy this, a radiance-based LST validation method has been developed at JPL for assessing accuracy of coarse-resolution hyperspectral sounder data. The new technique is showing very successful results.

Daniel Zhou [LaRC] reported on surface climatology data derived from three years of IASI measurements and its initial evaluation. The Namib and Kalahari Deserts are used for emissivity validation. Zhou further reports on the development of IR Surface Emissivity Climatology using IASI data. Zhou also showed statistics over Asia, China, and North America demonstrating cloud effects on retrievals using IASI data. In summary he states that a state-of-the-art retrieval algorithm, dealing with all-weather conditions, has been developed and applied to IASI radiance measurements.

Ronald Vogel [NOAA/NESDIS/STAR] reported on the use of surface emissivity datasets in radiative transfer models for data assimilation and evaluation of satellite-derived emissivity. Using the community radiative transfer model, a surface temperature error of 1K due to an emissivity error of 0.015 is determined. Two evaluation methods are used: observation minus simulation and a comparison of the University of Wisconsin IR emissivity module (UWIREMIS) against a validated dataset. The radiative transfer models require high-spectral resolution emissivity data developed from the assimilation of many channels from multiple satellite sensors. High spatial resolution is also required in the model and data in order to characterize emissivity variability of land surfaces. UWIREMIS satisfies both requirements.

Nicholas Nalli [NOAA/NESDIS/STAR] summarized the 2010 Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) Northeast Extension [PNE]/Aerosol and Ocean Science Expedition (AEROSE)-VI Ocean Validation Campaign. There have been a series of these trans-Atlantic intensive atmospheric field campaigns conducted aboard the NOAA Ship *Ronald H. Brown* the past few years to study dust and smoke aerosols. The AEROSE study domain spans a region of marine meteorological interest (for sounder missions) in terms of the Saharan Air Layer and its importance in tropical storm formation, and tropospheric ozone/carbon/aerosol chemistry and transport.

Session 9: New Methods & Retrievals

Zhouxia Pu [University of Utah] reported on the validation of AIRS temperature and moisture profiles over tropical oceans and their impact on numerical simulations of tropical cyclones. This work assesses the impact of AIRS retrieved temperature and moisture profiles on numerical simulations of tropical cyclones and examines the quality of AIRS retrievals and their biases in these environments and its impact on numerical simulations. Incorporating AIRS data products shows promise for improving the accuracy of tropical cyclone forecasts.

Sun Wong [JPL] reported on validating moisture profiles with NASA African Monsoon Multidisciplinary Analyses (NAMMA) Dropsonde Data. Dropsondes have limited sampling size, and water vapor has large spatial variability in the study region (35°–15°W, 5°–25°N). This work shows that AIRS has a moist bias for the dry conditions (i.e., when relative humidity (RH) is <~50%) and a dry bias from 500–600 hPa (where RH~5-6%) and also from 925–1000 hPa (where RH~5%); no significant biases are seen from 600–925 hPa. However, a larger sampling size is needed to confirm this result.

Evan Fishbein [JPL] reported on comparisons of simultaneous water vapor profiles from infrared and microwave (MW) sounders and inferences on IR sampling and microwave systematic errors. Fishbein showed comparisons of AIRS and MW profiles along a transect containing the radiosonde matching footprint. MW near-surface water vapor is biased high over land, but not over the ocean. The MW mid-troposphere water vapor is biased high over tropical oceans, but not the mid-latitudes.

Session 10: IR Radiance & Climate

Baback Moghaddam [JPL] reported on sparse eigen-decompositions for hyperspectral data. Algorithmic enhancements for sparse formulated linear discriminant analysis (Sparse-LDA) as a sparse regression problem speeds up optimization and reduces computer processing time by a factor of ~1000. A demonstration of an AIRS Cloudy/Clear sparse classifier has been made. Specifically, Moghaddam showed a case where he had separated cloudy and clear cases using AIRS Level 1 data.

George Aumann [JPL] reported on the subject of *Deep Convection or Anvil Clouds*. Deep Convective Clouds with "inverted" cloud top spectra (spectral inversion) are designated DCCi. DCCi with an associated greater than 4 K inversion (DCCi4) are associated with a type of deep convection that is so intense that it reaches and distorts the tropopause thereby indicating severe storms. A significant finding of this work is that the frequency of DCCi4 increases 53% for each degree Kelvin increase in the mean global sea surface temperature (SST).

Joel Susskind [GSFC] reported on the effect of El Niño/La Niña Oscillations on recent anomalies and trends of outgoing longwave radiation (OLR). A comparison of anomalies and trends of OLR from the Clouds and the Earth's Radiant Energy System (CERES) and AIRS are compared for September 2002–February 2010. Anomalies and trends of AIRS OLR closely match those of CERES, increasing confidence in both sets of observations. In addition, anomalies and trends of AIRS OLR can now be attributed to anomalies in other retrieved quantities such as temperature and water vapor.

Fengying Sun [NOAA/NESDIS/STAR] reported on OLR derived from AIRS radiance observations. The goal of the work is to produce CERES-like OLR type data from AIRS radiances and to extend the technique to IASI and other future hyperspectral sounders in order to make all the measurements traceable to CERES and later to the CLARREO instruments. Sun showed results from a least-squares regression between CERES OLR and AIRS radiance principal component scores. The AIRS OLR is in a good agreement with CERES OLR with a bias and standard deviation of 0.03 W/m^2 and 1.93 W/m^2, respectively. Large OLR differences (≥ 1 W/m^2) mainly occur in the twilight regions, in the South Polar regions, and over mid- and high-latitude dry land.

Session 11: Tropical Weather

Milton Halem [UMBC] reported on climate change to hurricanes, and how IR radiances from fraternal Aqua instruments validate AIRS products. Halem is moving towards implementing an eight-year fundamental decadal IR radiance record (FDIR) of gridded AIRS data at 0.50° x 1.00° for NOAA using 324 operational channels. AIRS/MODIS on Aqua are stable for eight years and are expected to be operational until 2018. Gridding these two IR radiance sensor datasets from the same satellite form a validated FDIR that can directly monitor global and regional decadal changes.

Kevin Garret [NOAA/NESDIS/STAR] reported on future plans for NOAA's microwave integrated retrieval system. NOAA/NESDIS/STAR has developed a flexible physical algorithm called the Microwave Integrated Retrieval System (MiRS), an operational algorithm at NOAA/NESDIS that provides operational sounding product and is expected to provide near-term improvements to sounding during heavy precipitation.

Eric Maddy [NOAA/NESDIS/STAR] reported on using collocated Advanced Very High Resolution Radiometer (AVHRR) and IASI measurements to constrain cloud-clearing and clear-column radiances from IASI. Cloud-cleared IASI brightness temperatures and clear-sky AVHRR brightness temperatures for surface sensitive channels agree in an root-mean-square sense to better than ~ 0.13 K for a variety of atmospheric conditions (e.g., land, ocean, clear, cloudy). They plan on extending the results using MODIS and AIRS data from NASA's Aqua satellite as well as to future VIIRS and CrIS data.

Mathias Schreier [JPL] reported on the variability of AIRS profiles and spectra during cloud transition. They are able to combine AIRS and MODIS radiances with high accuracy. The combination of the instruments helps to examine cloud properties and atmospheric profiles simultaneously, and the high resolution of MODIS can be used to define different cloud types. Distributions of cloud properties and profiles are not Gaussian and vary for different cloud types. High-resolution spectra from AIRS shows variation of brightness temperature for different cloud types.

Session 12: Instrument Calibration/Validation

Fred O'Callaghan [JPL] reported on the AIRS anomaly resolution process. The system uses orderly sets of flow charts based on the AIRS sub-systems as documented in the AIRS *e-Library*, with displays, diagnostics, operational procedures, and design information at each step. The system was designed to run on a *PC* or *Mac* platform using PDF file formats to access the AIRS *e-Library*. O'Callaghan gave a "walk through" of the AIRS January 2010 anomaly resolution and flow.

Denis Elliott [JPL] reported on a three-year comparison of AIRS and IASI co-located radiances for cold scenes. Data taken at Dome C, Antarctica—one of the coldest places on Earth—is used to check the performance of AIRS and IASI under difficult conditions and to identify possible issues. AIRS and IASI agree well with each other at scene temperatures less than 240 K at 1231/cm. However, at 1231/cm AIRS and IASI disagree above 240 K and IASI may not be reliable because of the internal cancellation of signal with instrument self emission. AIRS and IASI are very stable and calibration/validation artifacts are similar.

Dave Tobin [University of Wisconsin, Madison] reported on scan-angle dependence of AIRS/IASI comparisons using simultaneous nadir and off-nadir observations. Scan mirrors are different for each instrument; IASI uses gold (uncoated) and AIRS uses a Denton-coated silver 45° scan. Simultaneous off/nadir overpasses (SONOs/SNOs) are used for comparison. The IASI and AIRS field-of-view selections for SONOs and SNOs are +/- 20 min and 60 km. Approximately 8000 SONOs per off-nadir angle [+/-40°, +/-30°, +/-20°, +/-10°] are used in this study covering May 2007–November 2009. For SNOs, the mean differences between AIRS and IASI are on the order of <0.1 K. For SONOs, many more samples have been taken that do not have a scan angle bias resulting in quicker and/or more accurate intercalibration assessments. Radiometrically, there are no significant long-term changes in the SNO observed IASI–AIRS differences (slope vs time = 0.9 +/- 5.6 mK/year).

Larrabee Strow [UMBC] reported on spectral and radiometric issues for Level 1C. The work examines AIRS biases relative to ECMWF versus viewing angle. The conclusion to the work is that AIRS RTA has secant angle biases of up to 0.6 K. AIRS also has instrumental asymmetric cross-track biases of up to ~0.1–0.2 K. Polarization needs to be analyzed further. Doppler effects also contribute to biases. Examination of the secant dependence of the AIRS biases relative to ECMWF has proven very fruitful. Biases that we can attribute to AIRS or the RTA are significant for more demanding AIRS applications (e.g., CO_2).

Evan Manning [JPL] also reported on Level 1C—a cleaned-up version of Level 1B—to make an easier-to-use product. The Gap Filling Algorithm finds 10 channels anywhere in the spectrum that are a good match (and can also be interpolated between two channels), takes an average over these channels weighted by how well they match, and uses this value for the gap. The long-term spectral drift model includes terms for orbital cycle, seasonal cycle, and a general long-term drift. The Doppler Shift shows a maximum shift of 1.2 ppm for the edge field-of-views at the equator.

Session 13: NPP CrIS/ATMS

Mark Esplin [Utah State University, Space Dynamics Laboratory] reports on CrIS internal target emissivity check from *Day in the Life* test data. The CrIS sensor has completed thermal vacuum testing and is being integrated with the spacecraft. The longwave Internal Calibration Target emissivity in the engineering packs is slightly too high relative to the shortwave emissivity. A reasonable scan baffle temperature has been calculated from a scan scenario radiance error. A time-varying scan baffle temperature offset is planed for use on orbit.

Denise Hagan [Northrup Grumman Space Technology] reported on CrIS Calibration–Validation (Cal-Val) readiness for NPP. Three areas of Cal-Val match-up and sensor trending products use Product Generation Executables also known as flexible production tools. Cal-Val Analysis tools and other tools for radiometric, spectral, and geolocation validation have been developed. A series of calibration coefficients are derived for non-linearity trending and tuning robustness, instrument line shape (ILS) tuning and residual correction and sensitivity studies for the Scene Selection Module (SSM) Baffle Contribution to Target Radiance.

Antonio Gambacorta [NOAA/NESDIS/STAR] reported on the current status of NOAA IASI and NPP CrIS and ATMS retrieval algorithms. The IASI Retrieval System is being built to emulate the AIRS system, with the same executable being used for both instruments. AIRS and IASI have comparable performance, IASI root-mean-square and standard deviation water vapor performs better (~10%). Extensive validation using radiosonde observations is in preparation. The NOAA-Unique CrIS/ATMS Product System (NUCAPS) generates CrIS Cloud-clear Radiance (CCR) products for NWP centers and for the Comprehensive Large Array-data Stewardship System (CLASS). An important finding is that the AIRS water vapor retrieval channels should be optimized in the tropical regions rather than their original optimization for the U.S. standard atmosphere.

Murty Divarkala [NOAA/NESDIS/STAR] reported on validation of IASI environmental data records and prelaunch characterization of CrIS and ATMS the Cross-track Infrared and Microwave Sounding Suite (CrIMSS) environmental data records with IASI environmental data records, the ECMWF, and radiosonde observation measurements using the NOAA Retrieval Processing System to obtain validations. Proxy data are good, but bias-tuning is needed for the microwave (i.e., ATMS and CrIS) component.

Bill Blackwell [MIT] reported on the NPP ATMS instrument modeling and performance. Spectral assessments of frequency passband measurements and their performance impacts have been studied, with the result that the as-built spectral response function is a critical item to determine. Further, long-term stability assessments of the NPOESS transition to the JPSS Level 1 Requirements are detailed. Specifically, a threshold value of 0.05 K for the troposphere and 0.1 K for the stratosphere has been specified with a goal of 0.03 K (troposphere) and 0.05 K (stratosphere) over the mission's lifetime is sought.

Cheng-Hsuan Joseph Lyu [GSFC] reported on a JPSS/NPP/ATMS sensor performance study of the impact of the pre-flight module filter spectral response. The study acquired the original pre-flight module thermal vacuum tested filter spectral response function data to assure that the radiative transfer model uses an accurate filter response. Slightly different conclusions from the model results were found. The pre-flight module filter spectral response function does not have significant impact on the sensor performance.

Summary and Conclusions

The NASA Sounder Science Team Meeting was well attended with over 60 presentations in areas of weather, climate, atmospheric composition, and instrument behavior for AIRS/AMSU, CrIS/ATMS, and the IASI. These instruments have the highest impact on operational weather forecasting, but are also impacting research forecasting and analysis systems. Assimilation of IR sounder CO and CO_2 data has demonstrated improvement in the accuracy of modeled fields when compared to surface measurements. New scientific uses for sounder data are being found in the areas of cloud properties and dust, and new applications for sounding data are being found in diverse areas—e.g., human health. The scientific, operational, and applications benefits of atmospheric sounders continue to grow as the user community discovers the rich information content contained in these observations. More information and slides from the presentations given at the meeting can be found at the AIRS website: *airs.jpl.nasa.gov* under the documents tab. ■

announcement

ASTER GDEM Explorer (DEMEX) now available at the LP DAAC

The Land Processes Distributed Active Archive Center (LP DAAC) announces the release of the ASTER Global Digital Elevation Model (GDEM) Explorer tool, *DEMEX* (*demex.cr.usgs.gov/DEMEX/*). This tool can be used to browse and download ASTER GDEM data based on geographic areas of interest or predefined regions, including state, province, and county (for the U.S.). Data output from *DEMEX* is available in G*eoTIFF* or *ArcASCII* format. *DEMEX* is the result of collaboration between the LP DAAC and George Mason University's Center for Spatial Information Science and Systems.

ASTER Global DEM (GDEM) data are subject to redistribution and citation policies. Users of *DEMEX* are required to have an EOS Clearing House (ECHO)/Warehouse Inventory Search Tool (WIST) account to download data. Register for an ECHO/WIST account by going to *wist.echo.nasa.gov/~wist/api/imswelcome/* and selecting *Enter WIST*, then *Create Account*. For additional information, contact LP DAAC at: *lpdaac.usgs.gov/lpdaac/customer_service.*

2010 Precipitation Measurement Missions (PMM) Science Team Meeting

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Introduction

The Precipitation Measurement Missions (PMM) Science Team held its annual meeting in Seattle, WA, from November 1–4, 2010. The PMM Program supports scientific research, algorithm development, and ground validation activities for the Tropical Rainfall Measuring Mission (TRMM) and the upcoming Global Precipitation Measurement (GPM) Mission. Additional information about PMM can be found at: *pmm.nasa.gov*.

TRMM, a partnership between NASA and Japan Aerospace Exploration Agency (JAXA), was launched in 1997 and is in its thirteenth year of mission operation. GPM, a constellation satellite mission initiated by NASA and JAXA in partnership with other international space agencies, will extend current precipitation sensing capabilities from space with more accurate and frequent measurements over all latitudes. In July 2013, NASA and JAXA will launch the GPM "Core Observatory" carrying an advanced radar/radiometer instrument package in a non-Sun-synchronous orbit at a 65° inclination to unify and refine precipitation estimates from all constellation sensors. NASA will also provide a second radiometer to fly on a partner-provided Low-Inclination Observatory (LIO) at a 40° inclination to improve GPM constellation sampling for near real-time monitoring of hurricanes and more accurate estimates of rain accumulation. The LIO has a target launch date in late 2014.

The 2010 PMM meeting agenda comprised:

- updates on mission status, programmatic news, and other team business;
- scientific and activity reports from Principal Investigators (PIs) and international partners; and
- coordination of pre-launch algorithm development and ground validation activities for GPM.

The meeting had more than 170 participants from 12 countries that included representatives from NASA, JAXA, National Oceanic and Atmospheric Administration (NOAA), as well as universities, industry, and international partner agencies. The first three days of the meeting focused on TRMM/GPM programmatic summaries, international activities, ground validation plans, and science reports from new science team members in 12 oral sessions. In addition to the oral presentations, two afternoon poster sessions were held to facilitate discussion of research results in an interactive forum. The fourth day was devoted to GPM algorithm team meetings. Working groups focusing on hydrology, algorithm development, latent heating, and land surface characterization met throughout the week. On November 5, the NASA–JAXA Joint PMM Science Team held an invitation-only panel review of GPM sensor algorithms, confirmed the schedule for the next TRMM data reprocessing, and identified a list of candidates for GPM standard products.

Photo of the NASA Precipitation Measurement Missions Science Team Meeting participants

Programmatic Updates

Ramesh Kakar [NASA Headquarters—*GPM Program Scientist*] provided a NASA PMM Program status update, outlining seven NASA Earth science missions currently in formulation and implementation, including GPM. Kakar reported that TRMM instruments and spacecraft remain in excellent condition, and fuel use indicates that TRMM operations will likely overlap with GPM. He also described international participation in Ground Validation (GV) activities and gave an overview of several field experiments that have taken place to support GV.

Arthur Hou [NASA Goddard Space Flight Center (GSFC)—*GPM Project Scientist*] opened the first day's session and honored Joanne Simpson, the "heart and soul of TRMM," who passed away in March 2010. Hou introduced the new 2010-2013 PMM Science Team, which includes 59 domestic PIs and 19 international PIs from 11 countries. He presented an overview of PMM science activities, a series of GPM field campaigns in support of pre-launch algorithm development, and the integrated schedule and milestones for GPM science deliverables.

Scott Braun [GSFC—*TRMM Project Scientist*] provided an overview of TRMM-related activities and presented a status update for TRMM *Version 7 (V7)* algorithms. He discussed key differences between TRMM Precipitation Radar (PR) and TRMM Microwave Imager (TMI) algorithms, outlining several steps forward for resolving these discrepancies, including reprocessing of TRMM data—scheduled to begin in May 2011.

Art Azarbazin [GSFC—*GPM Project Manager*] provided an update on the GPM Core Observatory development, reporting that the High Gain Antenna has been assembled and meets all radio frequency requirements and the Core Observatory Lower Bus Structure is ready for Integration and Test. The integration timeline includes delivery targets of July 2011 for the Dual-frequency Precipitation Radar (DPR) and August 2011 for the GPM Microwave Imager (GMI).

Erich Stocker [GSFC] gave an update on the role of GSFC's Precipitation Processing System (PPS) in TRMM *V7* algorithm development, highlighting several issues that need to be addressed with *V7*. Stocker also reported that the Component Build 2 review is complete and all *V1* GPM algorithms are due to PPS for processing by November 30, 2011.

Thomas Wilheit [Texas A&M University] spoke about *consensus calibration* and how it will improve the performance of the TMI. Wilheit also announced that the Intersatellite Calibration (X-CAL) Working Group has completed a preliminary analysis of the JAXA Advanced Microwave Scanning Radiometer Earth Observing System dataset, and that the group is in the process of organizing a methods comparison for sounders.

Partner Activities

Programmatic status presentations from JAXA included **Riko Oki** [JAXA Earth Observation Research Center], who reported on improvements to the TRMM PR *V7* algorithm and GPM algorithm development, as well as Japanese participation in GV activities. **Toshio Iguchi** [National Institute of Information and Communications Technology] provided the status of DPR development for GPM. The DPR development test is complete and manufacturing of flight hardware is ongoing. The DPR will provide greater precipitation measurement sensitivity, increased sampling intervals, and guaranteed maximum measurement height compared to the TRMM PR.

Ralph Ferraro [NOAA] outlined NOAA's contributions to GPM, including an update on NOAA Polar Operational Environmental Satellites and the Joint Polar Satellite System, that will be included in the GPM constellation. He also presented on NOAA's participation on the PMM Science Team, Hydrometeorology Testbed (HMT) activities, satellite calibration activities, and GOES-R contributions to GPM.

Remy Roca [National Center for Scientific Research (CNRS) of France], **Marielle Gosset** [CNRS], and **Nicholas Viltard** [Pierre Simon Laplace Institute (IPSL) for Research and Environment] gave overviews of the French–Indian Megha-Tropiques (MT) mission, a satellite dedicated to increasing understanding of the water and energy cycle in the tropics, which will operate as a member of the GPM constellation. The team also reported on MT calibration/validation activities. MT is scheduled to launch in 2011.

Chris Kidd [University of Birmingham] and **Paul Joe** [Environment Canada (EC)] presented a proposal to the European Space Agency (ESA) for a Polar Precipitation Measurement (PPM) mission, to address current gaps in observational capabilities over polar regions and answer questions about high latitude precipitation. This information is vital to understanding the global water cycle, and will provide synergies with GPM.

The remaining international reports focused on ground validation, including project descriptions and status reports from **Dmitri Moisseev** [University of Helsinki], **Paul Joe** and **David Hudak** [EC], **Mi-Lim Ou** [Korea Meteorological Administration], **Luca Baldini** [Institute for the Science of the Atmosphere and Climate (ISAC) of Italy], and **Paola Salio** [University of Buenos Aires]. **Luis Machado** [Instituto Nacional de Pesquisas

Espaciais (INPE) of Brazil] described the pre-CHUVA[a] field campaign, which measured soil moisture in Alcântara, Brazil. Machado also outlined seven upcoming CHUVA field campaigns planned for 2011 and 2012 in Brazil. **Alessandro Battaglia** [University of Leicester, U.K.] reported on the Advanced Microwave Radiometer for Rain Identification (ADMIRARI) used in the Pre-CHUVA campaign. This campaign provides the unique opportunity to understand ground-based polarimetric observations of rainfall structure in three dimensions.

Applications Research and Land Surface Characterization

Several presentations from new team PIs described how PMM science applications are being used for flood and drought prediction, hydrological modeling, data assimilation, climate studies, land characterization, and emissivity. **Dennis Lettenmaier** [University of Washington] explained the economic impacts of floods and droughts worldwide, stressing the importance of focusing hydrological research on large river basins in the developing world. **Mekonnen Gebremichael** [University of Connecticut] discussed several satellite rainfall products that are being tested for hydrological modeling, and the need for sustainable satellite rainfall estimation in hydrologic applications.

Pingping Xie [NOAA Climate Prediction Center (CPC)] spoke about bias correction for the CPC MORPHing technique (CMORPH) to develop more accurate passive microwave rainfall propagation vectors. **Wade Crow** [U.S. Department of Agriculture] explained that soil moisture retrievals have a viable role in multi-sensor satellite precipitation products, citing that surface soil moisture products obtained from current (and planned) satellite missions contain useful information for global rainfall accumulation estimation over land. **Milija Zupanski** [Colorado State University (CSU)] spoke about using data assimilation to combine information from satellite observations and cloud-resolving models to improve short-term precipitation forecasts.

The remaining presentations focused on improving land surface characterization, which is essential for advancing over-land rainfall retrieval algorithms and satellite-based precipitation applications. **Joe Turk** [NASA/Jet Propulsion Laboratory] provided an overview of the Land Surface Working Group activities to compare independently-produced emissivity datasets over 12 unique areas. He concluded that surface emissivity is highly variable in space and time and its response to precipitation is an indirect means to compare and validate surface emissivity estimates. **Karen Mohr** [GSFC] presented findings from testbed activity in Tillabery, Niger to characterize changes in vegetation state in semi-arid surfaces as a result of seasonal rainfall, concluding that vegetation dynamics are strongly tied to interannual and intraseasonal rainfall variability. **Sid Boukabara** [NOAA National Environmental Satellite, Data, and Information Service (NESDIS)] reported on the Microwave Integrated Retrieval System (MIRS) and the algorithm's contribution to surface emissivity characterization for the GMI. **Fuzhong Weng** [NOAA NESDIS] summarized the Microwave Integrated Land Emissivity System (MILES), which compares emissivity and snow depth.

Ground Validation

Walter Petersen [NASA Marshall Space Flight Center] and **Mathew Schwaller** [GSFC] gave an overview of GPM GV activities, from pre-launch algorithm development to post-launch product evaluation. They outlined pre-launch GV activities, including the Brazilian Pre-CHUVA campaign (March 2010), the Light Precipitation Validation Experiment (LPVEx) in Finland (September–October 2010), and upcoming campaigns, including the Mid-Latitude Continental Clouds and Convection Experiment (MC3E) planned for Spring 2011, the GPM Cold-Season Precipitation Experiment (GCPEx) in early 2012, and NOAA's Hydrometeorological Testbed in the southeastern U.S. (HMT-SE) in 2013. Field campaigns will utilize NASA's Dual-Polarimetric Radar (NPOL), a NASA Ka-Ku Dual-Frequency Dual-Polarimetric Doppler Radar (D3R), and GPM Disdrometer and Radar Observations of Precipitation (GPM-DROP) instrumentation, and other aircraft and ground measurements.

Walter Petersen, Tim Schneider [NOAA Earth System Research Laboratory], and **Dmitri Moisseev** detailed the MC3E, HMT-SE, and LPVEx field campaigns, respectively. MC3E seeks to improve rainfall retrievals over mid-latitude land surfaces, while the HMT-SE experiment will focus on warm season precipitation over terrain and the resultant implications for hydrologic applications of satellite-precipitation estimates. The just-completed LPVEx campaign represents collaboration between NASA's CloudSat and GPM missions, the Finnish Meteorological Institute, and the University of Helskinki. LPVEx employed an array of ground-based polarimetric and vertically-pointing radar, disdrometer observations, and *in situ* aircraft data collections motivated by the disparity among satellite products to estimate the frequency and accumulation of light rainfall at higher latitudes characterized by shallow freezing levels.

Initiating a ramp-up in planning for GPM integrated hydrologic validation, a sequence of discussions was held to evaluate plans for potential integrated Hydrology GV activities. **Wade Crow** described the Walnut Gulch and San Pedro watersheds in southeastern Ari-

[a] CHUVA is not an acronym; it is the Brazilian word for rain.

zona as potential locations for a field campaign during the monsoon season. Crow noted that the extensive observational network in this region as well as coordination with Soil Moisture Active-Passive (SMAP) validation activities will provide an excellent opportunity to evaluate and characterize background land-surface emissivity and measure evaporation effects in a semi-arid environment. **Robert Houze** [University of Washington] discussed the possibility of using the Olympic Mountains in Washington as a "natural laboratory" for precipitation studies in orographic settings, while **Witold Krajewski** [University of Iowa] described the heavy rainfall and high flood rate in Iowa as ideal for studying the role of rainfall verses non-rainfall factors in flood genesis. Concurrent to and in association with these discussions, the PMM Hydrology Working Group is refining the set of objectives to be pursued within the aforementioned activities and integrating the objectives toward creating an updated plan for conducting GPM Integrated GV.

Algorithm Activities

Robert Meneghini [GSFC], **Chris Kummerow** [CSU], and **Bill Olson** [University of Maryland, Baltimore County Joint Center for Earth Systems Technology] provided status updates for the radar, radiometer, and combined radar–radiometer algorithms, respectively. These presentations discussed the theoretical frameworks, algorithm research, and validation activities for each algorithm. **Courtney Shumacher** [Texas A&M University] reported on the evolution of the PR algorithm and its dependence on attenuation correction and Z-R[b] choices in relation to ground sites and physical results, especially over land. **Toshihisa Matsui** [GSFC] provided a status update on the Synthetic GPM Simulator while **Simone Tanelli** [JPL] outlined recent upgrades to the Airborne Precipitation Radar-2 dataset and algorithm suite. **Steve Durden** [JPL] explained why the Surface Reference Technique (SRT) is better suited for applications over ocean rather than land and proposed using SRT for surface properties and Path Integrated Attenuation (PIA) characteristics for rain properties to determine the best algorithms for land and ocean. **Darren McKague** [University of Michigan] reported on X-CAL activities at the University of Michigan, where the team is working to develop accurate, stable brightness temperatures that are consistent from sensor to sensor.

An important advancement of GPM will be the ability to measure light rain and falling snow in middle and high latitudes. **Ralf Bennartz** [University of Wisconsin] spoke about assessing ice scattering models against available active and passive satellite observations to create a GPM proxy dataset. **Andrew Heymsfield** [National Center for Atmospheric Research] explained the difficulty in determining radar reflectivity and calculating snowfall rates. **Pavel Groisman** [University Corporation for Atmospheric Research/National Climatic Data Center] described the importance of bias-adjusting precipitation time series in high latitudes to distinguish between true changes in precipitation and indirect impact of global warming on the measured fraction of precipitation. **Gerald Heymsfield** [GSFC] explained the importance of the time evolution of convection and the use of strongly attenuated radar in combination with weakly attenuated radar to better understand convective structure in ice regions.

Algorithm development and instrument validation are essential components of PMM Science Team activities for improving TRMM products and preparing for the launch of the GPM Core Observatory. Progress has been made on the TRMM *V7* algorithms, with ongoing improvements and processing continuing into the spring of 2011. GPM algorithm teams met on November 4 to discuss radar, radiometer, and combined algorithm development for the GPM Core Observatory as well as multi-satellite algorithm strategies. GPM algorithm teams for Level 2 and Level 3 data products will submit to the Precipitation Processing System (PPS) the following items: 1) Algorithm Theoretical Basis Documents by November 30, 2010; 2) Baseline Algorithm Codes by November 2011; and 3) At-Launch Codes by November 2012 to support the launch of the GPM Core Observatory in July 2013.

Summary

The 2010 PMM Science Team Meeting provided a forum to review the current status of TRMM and GPM Mission activities as well as report on a range of scientific advancements, partner activities, and algorithm developments. Specific topics included outlining TRMM's development and testing of TRMM *V7* algorithms for data reprocessing, to begin in May 2011, and several discussions detailing advanced satellite-based applications that will markedly improve precipitation measurements with the launch of the GPM Core Observatory. Ground Validation activities were also discussed in detail, including summaries of three PMM Program field campaigns in 2010—one in Brazil jointly with INPE studying warm rain processes (March), one over the tropical Atlantic and Caribbean studying hurricane Genesis and Rapid Intensification Processes (GRIP) in August–September, and one jointly with CloudSat and FMI focusing on low-altitude melting layers over the Gulf of Finland in September–October. Upcoming field campaigns include the MC3E, jointly with the Department of Energy in central Oklahoma in April-May, 2011 and the NASA-EC GCPEx in Ontario, Canada in early 2012. ■

[b] Z-R is an empirical relationship between radar reflectivity and rainfall rate.

HyspIRI Science Workshop Summary

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Approximately 180 scientists gathered from August 24–26, 2010, at the 3rd NASA Hyperspectral Infrared Imager (HyspIRI) Science Workshop held in Pasadena, CA. PDF versions of the presentations given at the meeting are available from the HyspIRI website (*hyspiri.jpl.nasa.gov*).

Introduction and Meeting Overview

The HyspIRI mission was recommended for implementation by the 2007 report from the U.S. National Research Council *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (also known as the Earth Science Decadal Survey or, simply, the Decadal Survey). The annual HyspIRI workshop provides an open forum to present the observational requirements for the mission and assess its anticipated impact on scientific and operational applications; the open forum also provides an opportunity to obtain feedback from the broader scientific community on the mission concept. This year's workshop had a greater emphasis on the science contribution from HyspIRI and, in particular, its contribution to climate science. There also was more emphasis on the potential contribution to science applications with recent examples from the oil spill in the Gulf and the volcanic eruption in Iceland. The morning of the first day focused on providing an overview of the mission. The afternoon of the first day focused on climate related talks. The second day was primarily science presentations, including discussion of the science questions that HyspIRI will address. The final day included discussions of related missions, partnership opportunities and plans for 2011 and beyond. Of particular interest was the discussion of a potential airborne campaign to acquire data for both science and algorithm testing beginning in the 2011-2012 timeframe. As at last year's meeting, there was a review of the Preliminary Level 1 mission requirements. This year there were over 25 posters which provided an excellent opportunity for more detailed discussions between talks. The workshop participants concluded that the HyspIRI mission would provide a significant new capability to study ecosystems and natural hazards at spatial scales relevant to human resource use. The participants felt the measurement requirements could be achieved with the reference instrument design concepts and be implemented through the use of current technology. The workshop participants endorsed the recommendation of the Decadal Survey itself, and reiterated the need for the HyspIRI mission; they felt the mission, as defined, would accomplish the intended science.

HyspIRI Science Workshop Participants

Woody Turner [NASA Headquarters (HQ)—*Co-Program Scientist for HyspIRI*] started the meeting by welcoming the participants and outlining the goals and objectives for this year's meeting. Turner noted that the science focus this year would be on climate but there would also be several key talks on the potential of using HyspIRI for applications research, and in particular, disaster response—illustrated by talks on the recent Gulf oil spill and volcanic eruption in Iceland. He noted that since the last workshop we have had a symposium at Goddard Space Flight Center (GSFC) that focused on higher level ecosystem products as well as largely completed two reports addressing certain critical aspects of the mission (i.e., sun glint and hot target saturation). Turner also highlighted the opportunities for international partnerships and welcomed the large number of international investigators present at the workshop. He closed by stating that the mission concept is clearly defined, utilizes mature technologies and is low cost, and is ready to go!

Jack Kaye [HQ—*Associate Director for Research and Analysis, Earth Science Division*] further emphasized the importance of climate observations. Kaye noted that there will be a National Climate Assessment in 2013 and NASA would play a key role. He discussed the possibility of the acquisition of a HyspIRI-like airborne dataset for NASA science and HyspIRI algorithm testing which also could contribute to the climate assessment.

HyspIRI will have three main payload elements, a Visible Shortwave Infrared imaging spectrometer (VSWIR), a multispectral thermal infrared (TIR) imager, and an Intelligent Payload Module (IPM). The next series of presentations gave details on these elements.

Rob Green [NASA/Jet Propulsion Laboratory (JPL)] identified how HyspIRI would provide critical climate observations and noted that the Decadal Survey had explicitly cited the need for HyspIRI for climate. He also summarized the instrument concept for the VSWIR. The VSWIR imaging spectrometer will obtain data covering the spectral range from 380–2500 nm with 10 nm sampling. VSWIR data will be acquired over the full terrestrial surface with a 19-day-revisit, including shallow water regions. The deep oceans and ice sheets also will be acquired with a 19-day-revisit but resampled to a spatial resolution of 1 km. Green presented examples of how the VSWIR data would be used for a range of science challenges, primarily focused on ecology, including mapping species and canopy chemistry. **The VSWIR system will provide the same level of spectrometer coverage in 1 year that it would take current and future full solar reflected range imaging spectrometers 100 years to provide.** The VSWIR instrument concept was shown to have design heritage from instruments such as the Moon Mineralogy Mapper (M3). This heritage has allowed the VSWIR instrument to be far smaller and use less power than earlier designs such as Hyperion on the Earth Observing-1 mission. In-flight, the instrument would be fully calibrated with an onboard solar panel, lunar looks, and ground calibration experiments. Green closed by reiterating that the VSWIR concept was mature and ready to go.

Simon Hook [JPL] summarized the instrument concept for the thermal infrared (TIR) multispectral imager on HyspIRI. The TIR imager will obtain data in eight spectral channels; one of the channels is located at 4 μm and the other seven channels are located between 7–12 μm. TIR data will be acquired over the full terrestrial surface with a 5-day-revisit, including shallow water regions. The deep oceans and ice sheets also will be acquired with a 5-day-revisit but resampled to a spatial resolution of 1 km. Hook presented examples of how the TIR data would be used for a broad range of science and applications with particular emphasis on volcanoes, wildfires, and water use and availability. For each area, Hook provided examples of how the instrument concept was designed to address critical questions in that area. The TIR instrument operates continuously, providing both a daytime and nighttime scene for the entire Earth every five days at the equator. He showed how the revisit will be greater at higher latitudes and used an example from the recent Iceland eruption to highlight how the TIR would have been able to provide daily information on the composition and chemistry of the volcanic plume—of particular importance for aeronautics. The TIR instrument concept has design heritage from instruments such as the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Moderate Resolution Imaging Spectroradiometer (MODIS) and is a mature concept that can be built and launched in the same timeframe as the VSWIR instrument. In-flight, the instrument will be calibrated with a two-point calibration, obtained by viewing an onboard blackbody and deep space every scan. There also will be lunar looks and ground calibration using automated validation sites. Hook closed by restating that the TIR will provide essential data for reducing the uncertainties in land carbon flux together with data for a range of applications from volcano monitoring to wildfires.

Carl Bruce [JPL] provided more detail on the VSWIR reference design concept. Bruce stated that this year's effort had focused on checking the mass and power requirements and confirming the instrument met certain key requirements. This included numerical modeling of the signal to noise and uniformity. He noted the VSWIR system will be a high data rate system with no new technology needing to be developed as the critical parts are at Technology Readiness Level (TRL) 6. Antecedent data are available from the MApping Reflected energy Spectrometer (MARS) instrument, a similar design to the VSWIR instrument, and together with data from the upcoming Airborne Visible/Infrared Imaging Spectrometer–Next Generation (AVIRIS-NG) will provide valuable information on the nominal design concept. Current plans call for ground control points in order to meet the 30-m geolocation accuracy requirement. There are some differences between the HyspIRI concept and the M3; for example, the VSWIR instrument will use two identical spectrometers, have a larger radiator and use four detectors compared to a single detector in M3. These differences will not impact the reference design concept which continues to be optimized. The VSWIR instrument is possible because of several key technologies that have been developed over the last decade such as curved electron-beam fabricated gratings and uniform slits which enable a highly uniform imaging spectrometer to be built.

Marc Foote [JPL] then provided more information on the TIR reference design concept. The TIR instrument will be a whiskbroom scanner with a 51° total field of view and ground resolution of 60 m. The data will be collected with a two-sided scan mirror. The dwell time for any given pixel will be 32 microseconds. The system will use a Mercury Cadmium Telluride detector and the focal plane will be cooled to 60 K with an active cooler. The scan mirror will use a lower resolution controller combined with a higher resolution interferometric encoder for high pointing knowledge. A two point calibration (viewing a blackbody and deep space) will be performed every two seconds. The system will use a Cassegrain telescope with radiation from the instrument baffled away from the detector. There will be a single detector array, having 32 readout ports, with 256 x 16 pixels in each of the eight spectral channels. The system will use time delay and integration with each channel using four columns from the array—since each channel has extra columns, the best four columns can be used. Current testing of a prototype read-out integrated circuit indicates compliance with noise and power specifications, and the instrument noise-equivalent temperature difference should be less than 0.2 K in the seven thermal infrared channels, with ample signal from hot targets for the mid-infrared channel. Various commercial cryocoolers are being studied with several available that meet the design requirement.

Dan Mandl [NASA/Goddard Space Flight Center (GSFC)] described the Intelligent Payload Module (IPM) that will provide low-latency data, which can be used for a wide range of applications such as near-real-time (NRT) monitoring of fires or floods. There will be two data streams on the spacecraft; one is downloaded through the normal route while a second identical stream goes to the IPM. The IPM will be able to subset and process this second stream and download the data in NRT via a direct-broadcast antenna. The NRT data will be available over the Internet. Work is currently underway on benchmarking the Computer Processing Unit for IPM and developing delay tolerant network communication connectivity to handle any network disruption. The web coverage service will be used to automatically load algorithms so a custom algorithm can be loaded for a particular task or application and the data downloaded in NRT such as during a fire or flood. An IPM testbed for HyspIRI has been developed and is being used for testing algorithms such as automated atmospheric correction using existing Hyperion data.

Bogdan Oaida [JPL] discussed the overall mission concept. HyspIRI is planned to be in a 626 km Sun-synchronous orbit with a 10:30 AM descending equatorial crossing time. Oaida showed there are several other potential orbits that could support the 19-and 5-day revisit of the VSWIR and TIR respectively, including an orbit around 705 km used by many other spacecraft—e.g., the A-Train. He outlined the operations concept for HyspIRI, which is very simple since both instruments are always turned on in order to provide global mapping. The VSWIR data are day-only data and currently planned to be acquired when the solar elevation is greater than 20°, however, this constraint may be relaxed to 10° to provide additional coverage in the polar regions. This year the results from the 2009 concept study were reviewed and the mass confirmed to meet the design principle for JPL. Multiple spacecraft solutions are available which would be modified to add power and an onboard recorder. Several launch vehicles are available which would meet the requirements. The ground systems and data management concept continues to mature. In a response to a Request For Information, Norway's Kongsberg Satellite Services (KSAT) has indicated they will have ample capacity to meet the downlink needs of HyspIRI with two polar downlink stations.

Rob Green and **Simon Hook** reviewed the Draft Level 1 Mission Requirements that serve as the top-level requirements for the HyspIRI mission and provide the basis for deriving the more detailed Level 2 requirements. These requirements were first presented at the 2008 Workshop and are reviewed at each workshop to make sure the community is fully aware of the data that HyspIRI will provide.

Greg Asner [Carnegie Institution for Science, Stanford University] then gave the first of two keynote presentations highlighting the key climate contributions of HyspIRI. Asner began by noting that biospheric and cryospheric feedbacks are two major uncertainties that need to be resolved to understand and predict climate change. Changes in greenhouse gas emissions are controlled by biospheric feedbacks, and although the different biospheric processes are known, we do not understand their relative contributions. For example, temperature changes can result in a large re-shuffling of plant functional types, including changes in invasive species and nitrogen fixing plants. This re-shuffling results from drier and warmer conditions, which then leads to new feedbacks. Invasive species may grow faster but only if higher temperatures and light are available with sufficient nutrients and moisture. Invasive plants and other changes in plant functional types can result in significant changes in nitrogen cycling and thus levels of the greenhouse super-gas nitrous oxide. New plant functional types may store less carbon or have a different albedo which in turn can result in a new feedback. Studies have shown that by combining imaging spectrometer data with model data, e.g. the Carnegie Ames Stanford Approach (CASA), these fluxes can be obtained. This information cannot be obtained from current coarse spatial and spectral resolution measurements. Asner noted that the Intergovernmental Panel on Climate Change (IPCC) is currently trying to determine whether a biospheric feedback is taking place in the Amazon, which in recent years has been getting ~1% drier every 3 years. A recent paper using MODIS data suggested the Amazon became greener during droughts but subsequent studies suggested this was an artifact in the MODIS data. HyspIRI will provide the measurements needed to observe and understand this shift in plant functional types that coarser spatial and spectral resolution instruments cannot provide. He also reported that HyspIRI will provide valuable information on albedo feedbacks, fire emissions, and evapotranspiration. Asner noted that current sensors are underestimating fire emissions since they do not resolve the contribution from many agricultural and forest fires that are typically smaller than large wildfires. The global mapping capability of HyspIRI is critical to fully understand these feedbacks. (Other missions provide detail on local processes but HyspIRI will provide the core measurements for understanding what is happening globally.) HyspIRI measurements would be even more powerful when coupled with data from other systems which provide plant structural information such as the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission. Finally, Asner emphasized that the IPCC needs this information as soon as possible to understand what changes are happening now and to better predict what will happen in the future.

Tom Painter [JPL] gave the second keynote presentation on albedo feedbacks associated with dust and black carbon (BC) in snow. As noted in the recent IPCC reports albedo changes can have a radical effect on climate, but at present our knowledge of albedo feedback is very limited. This lack of knowledge occurs because *in situ* radiation measurements are expensive and sparse, and quantitative retrievals from current remote-sensing technology are not possible. Information about changes in snow albedo is critical but more improved measurements are needed to understand the impact of BC and dust. A key area where such knowledge is important is the *down wasting*[1] of Himalayan glaciers due to increasing warming and a combination of BC and dust. We know that down wasting is taking place but do not understand how much of this down wasting comes from changes in climate and radiative forcing by BC and dust. Likewise, changes in snowmelt have a critical impact on water resources such as in the Southwest U.S. In the Upper Colorado River basin, point models indicate that increasing dust from land-use/land-cover change in the desert southwest has reduced snow cover by 28–50 days. Current data from coarse spectral resolution sensors such as MODIS does not provide information where the albedo differences are greatest and easiest to measure. The higher spatial and spectral resolution of HyspIRI allows the retrieval of radiative forcing by dust and black carbon, fractional snow cover, snow grain size, and albedo.

Science Presentations

After the two keynote presentations the remainder of the first day, all of the second day, and part of the third day were devoted to science talks. There were over 40 talks and the presentations associated with these talks are available from the HyspIRI website listed earlier. The talks covered a wide range in topics and included updates from the studies funded by NASA solicitations as well as updates on the key science questions that HyspIRI will address. The science questions were developed in conjunction with the Science Study Group, a group of scientists appointed by NASA to help guide the mission and ensure the measurements are of maximum benefit. The science talks included multiple presentations related to the application of the science data, in particular, recent results from the Gulf oil spill. HyspIRI-like imaging spectrometer data from the Gulf oil spill were obtained with the AVIRIS instrument. These data were used to determine the surface oil thickness and oil-to-water ratio, a new technique that greatly aided the response because to date there have been no technologies to derive oil slick thickness other than human observation and measurement. Thus, coarse spatial and spectral resolution sensors and Synthetic Aperture Radar (SAR) sensors can determine the presence of oil on the surface but are unable to determine if a thin film (i.e., sub-micron) is present or a thick (i.e., cm-scale) oil layer. The high spectral resolution of AVIRIS and HyspIRI will allow quantification of the amount of oil to guide response efforts, and to improve predictive capabilities. AVIRIS data also were acquired over the coastal wetlands for the entire Gulf region both before oil washed onshore and afterwards. These data will be used in ongoing studies to better understand the impact of the oil spill and remediation techniques on the fauna and flora of the wetlands around the Gulf.

[1] *Down wasting* is the stationary thinning of the glacial ice.

The third and final day of the workshop began with a short report on the recent HyspIRI Symposium arranged by **Betsy Middleton** [GSFC] and colleagues. The focus of the symposium was the higher-level data products, especially those related to ecosystem studies. Middleton highlighted the plethora of products that HyspIRI could potentially produce and noted such products will be critical in understanding the carbon budget. She also identified that more frequent revisits in the northern latitudes will be particularly advantageous given these regions are undergoing rapid change.

Middleton's presentation preceded a series of talks from our international colleagues and included presentations from Germany, Italy, Japan, Argentina, and Australia, each of which highlighted the capabilities within each country and how their respective efforts would dovetail with the unique HyspIRI global mapping mission. These included downlink opportunities as well as joint calibration and validation experiments.

The remainder of the morning and early part of the afternoon included a mixture of science and engineering presentations. These included more detailed presentations on the orbits, coverage, and downlink procedures. For example, **Bob Knox** [GSFC] discussed the benefit of the increased number of opportunities with latitude and noted how the TIR sensor would provide daily coverage in the northern latitudes. **Alexander Berk** [Spectral Sciences, Inc.] described updates to the MODTRAN®[2] radiative transfer model and how these would benefit the HyspIRI mission. For example a recent update for modeling gas plumes could be used for modeling volcanic eruption plumes. **Susan Ustin** [University of California Davis] gave a short presentation on a small workshop she is organizing on developing global HyspIRI data products.

[2] MODTRAN computer software is a registered trademark owned by the United States Government as represented by the Secretary of the Air Force.

Review of the Workshop and Next Steps

The final presentation reviewed the progress since the last meeting and future activities. Excellent progress has been made since the last meeting with additional reports such as the sunglint and hot target saturation reports that provide invaluable feedback on the measurement requirements for the instruments. Participants noted the large number of posters displayed at the meeting and asked that future meetings included an evening session dedicated to the posters. Of particular interest with the community was the possibility of an airborne campaign in California using the AVIRIS and the MODIS/ASTER Airborne Simulator (MASTER) sensors to acquire HyspIRI-like datasets for both science and algorithm development. Potential flight corridors were discussed together with how to ensure the necessary field measurements were made to maximize the usefulness of the data.

In summary, the participants felt that the HyspIRI Level 1 Mission would provide a significant new capability to study ecosystems and natural hazards at spatial scales relevant to human resource use. The participants confirmed the Draft Preliminary HyspIRI Mission Level 1 Requirements were achievable with the mission concept presented and would provide the data necessary to address the science questions identified for the mission.

Aspen Global Change Institute Workshop on Global Change and the Solar-Terrestrial Environment

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Approximately 30 scientists gathered for the 2010 Aspen Global Change Institute (AGCI) Workshop, Global Change and the Solar-Terrestrial Environment, June 12-17, in Aspen, Colorado. ***Editor's Note:*** *The scope of the topics covered in this article is a bit wider than many of our articles in* ***The Earth Observer.*** *The discussions covered a wide range of current solar and Earth science topics relevant to global change research.*

A summary of the meeting, including PDF versions of many of the presentations, is available at *www.agci.org/programs/past_scientist_workshops/about_the_workshop/sciSess_details.php?recordID=265.*

Introduction and Workshop Overview

The Aspen Global Change Institute (*www.agci.org/index.php*) hosted a workshop, *Global Change and the Solar-Terrestrial Environment*, from June 12-17, 2010. AGCI has a twenty-year history of initiating and facilitating highly successful interdisciplinary meetings exploring global environmental change and Earth system science with an emphasis on societal interactions.

The purpose of the 2010 workshop was to assess the level of understanding of the solar-terrestrial system in relation to recent advances connecting solar changes to changes in Earth's global environment, identifying gaps in our knowledge, and identifying interdisciplinary research topics to improve predictions of solar-terrestrial influences on Earth's global environment and its people. The full range of global change forcings and feedbacks, including those of human-induced origin, were part of the framework for the discussions.

Members of the organizing committee were **Rick Chappell, Richard Fisher, Barbara Giles, Ernie Hildner, John Katzenberger, Jack Kaye**, and **Jim Spann**. The Workshop Chairs were **Lesley Gray**, **Charles Jackman**, **Paul Kintner** (recently deceased), **Peter Pilewskie**, and **Howard Singer**. The workshop was supported by the NASA Earth Science and Heliophysics Divisions.

In keeping with the strong interdisciplinary nature of the workshop, participants represented a broad range of expertise, including heliophysics, atmospheric chemistry and radiation, climate modeling, space weather, and biology/ecosystems, among others. The workshop emphasized the importance of identifying and discussing the consequences of less than one-year, to decadal, to multi-decadal variations through which the solar-terrestrial environment affects global change. Topics included decadal and longer-term variability in solar irradiance, the slowly weakening terrestrial magnetic field and its influence on solar and cosmic ray energy reaching the atmosphere and the biosphere, the solar magnetic field and solar wind, and many other topics. Particular emphasis was placed on the representation of these processes in climate models, the quantitative testing of process models, and the scientific efforts that can contribute to their future verification.

The workshop was organized into the following nine sessions, integrated to promote cross-disciplinary discussion and interaction: Heliophysics and Space Climate, Climate Impacts and Response, Lower Atmosphere/Solar Response, Climate Impacts of Aerosols/Clouds, Charged Particles and Geomagnetic Effects, Education and Public Outreach, Solar Variability and Influences, Solar Cycle/Atmosphere Effects, and Middle and Upper Atmosphere Effects.

Heliophysics and Space Climate

Jim Spann [NASA Marshall Space Flight Center] opened the session with his talk *Heliophysics 2009 Roadmap and Global Change: Possibilities for Improved Understanding of the Connection,* explaining that heliophysics relates to global change through its study of solar variability and how this modulated energy flows through the near-Earth space environment and affects the terrestrial atmosphere. Heliophysics is also relevant to global change as reflected by space weather's changing impacts to society's technical systems. Spann listed the connecting science themes that served as motivation for the workshop, and outlined the six science targets of NASA's heliophysics roadmap.

Howard Singer [National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center] discussed the relationship between solar cycle variations and the outer magnetospheric mass density determined through the analysis of magnetic oscillations observed by the Geostationary Operational Environmental Satellite (GOES) system. Increasing ionospheric mass density is important for radiation belt climatology and its impacts on satellite operations. Singer stated that lessons from how we deal with the societal and economic impacts of space weather can provide guidance for dealing with climate and global change.

Climate Impacts and Response

Don Wuebbles [Department of Atmospheric Sciences, University of Illinois] discussed *Solar Influences on Climate Change and Resulting Impacts: Past and Near Future*. Wuebbles explained that the last four decades of climate change have largely been driven by human activities, with solar forcing playing almost no role. In fact, since the beginning of the industrial revolution the Sun can explain less than 15% of the overall changes in climate. Nevertheless, solar variability can influence the range of projected impacts resulting from human-induced climate change.

Peter Pilewskie [Laboratory for Atmospheric and Space Physics (LASP), University of Colorado (CU)] discussed the importance of solar spectral irradiance (SSI) in determining the climate response to solar variability. Traditionally, almost all attention in Sun-climate influences related to SSI has been focused on the ultraviolet region of the spectrum, its variability, and subsequent impact on ozone. However, the Solar Radiation and Climate Experiment (SORCE) has allowed new measurements of SSI in the visible and near-infrared regions—where the largest absolute solar variability occurs. Perhaps these new measurements will reveal other mechanisms, including feedbacks in the hydrological cycle that might influence the Sun's impact on climate.

Lower Atmosphere/Solar Response

Jerry Meehl [National Center for Atmospheric Research (NCAR)] gave a talk on *Amplifying the Pacific Climate System Response to a Small 11-year Solar Cycle Forcing*—also the topic of his 2009 paper in *Science*. The basis for the work was to gain insight into the mystery of how the relatively small fluctuations of the 11-year solar cycle can produce the magnitude of the observed climate signals in the Tropical Pacific associated with such solar fluctuations. Solar cycle maximum forcing produces sea surface temperature (SST) and precipitation anomalies with a La Niña-like pattern in the Pacific. Meehl included two mechanisms—the top-down stratospheric response of ozone to fluctuations of shortwave solar forcing, and the bottom-up coupled ocean-atmosphere surface response—in versions of three global climate models and showed that, acting together, they: 1) enhance the climatological off-equatorial tropical precipitation maxima in the Pacific; 2) lower the eastern equatorial Pacific SSTs during peaks in the 11-year solar cycle; and 3) reduce low-latitude clouds to amplify the solar forcing at the surface.

Lesley Gray [Department of Atmospheric, Oceanic and Planetary Physics, Clarendon Laboratory, Oxford University] gave an overview of her recently published review paper, *Solar Influences on Climate* [*Rev. Geophys*, 2010]. Gray explained that the stratosphere plays a role in transmitting the signal of solar variability to the Earth's surface. Increased temperatures are seen at solar maximum due to direct heating effects by increased irradiance and indirect heating due to increases in ozone. Increases in ozone impact wave propagation deep into the atmosphere, influencing circulation and weather patterns at the Earth's surface—the so-called *top-down* mechanism. This has been tested in chemistry-climate models that capture the broad signatures of solar response seen in the observations. However, other details require more attention, resulting in an insufficient understanding of the exact mechanism for the extension of influence to the Earth's surface. Model studies that include a coupled ocean are required, so that the relative influences of the top-down and bottom-up mechanisms, and the feedbacks between them, can be better understood.

Lon Hood [Lunar and Planetary Laboratory, University of Arizona] spoke on *The Stratospheric Response to 11-Year Solar Variability: Direct UV Forcing and the Possible Role of Ocean-Troposphere Feedbacks*. Hood explained while the upper-stratospheric variations in ozone and temperature are closely linked to solar ultraviolet variability, variation in the lower stratosphere is less understood. It is likely dynamical in origin but has not yet been fully simulated in chemistry-climate models. The 11-year El Niño-Southern Oscillation (ENSO)-like signals in the tropical Pacific can be simulated by models when solar stratospheric forcing and an amplifying ocean-troposphere response is included, raising the possibility that this same mechanism may amplify the lower stratospheric response. Ultimately, the lower stratospheric response to 11-year solar forcing may represent a positive feedback for solar climate forcing.

Daniela Lindner [University of Illinois at Urbana-Champaign] discussed *Modes of Variability in Observed Near Surface Temperatures*. Lindner showed that the climate system displays various modes of variability, ranging from intra-seasonal to inter-decadal time scales. Using non-parametric *Singular Spectrum Analysis* to study quasi-periodic oscillations revealed five statistically significant oscillations due to natural variability with periods ranging from 4–69 years. The oscillations were present in all oceanic regions except the Eastern Equatorial Pacific Ocean, and in the land regions surrounding the North Atlantic Ocean. She listed possible causes for all five significant oscillations.

Climate Impacts of Aerosols/Clouds

The lone presentation in this session was made by **Ralph Kahn** [NASA Goddard Space Flight Center (GSFC)] and called, *Aerosols and Climate: What We Can Say, and What We Can't*. Kahn reviewed what we know about global aerosol amount and type based on satellite, airborne, and surface observations. There are significant uncertainties in the quantitative constraints these data place on global-scale direct aerosol radiative forcing, and they provide very limited, qualitative constraints on the indirect effects aerosols have on clouds. Although further refinement of the current aerosol products is possible, major advances will require much greater integration of satellite and suborbital data with models.

Charged Particles and Geomagnetic Effects

Richard Mewaldt [California Institute of Technology (Caltech)] reviewed how the cosmic-ray intensity has varied during the space era and described how these variations are related to solar activity and solar-wind variations. He discussed efforts to relate the Beryllium-10 (Be-10) and Carbon-14 records over the last 10,000 years to other solar-activity records, including the interplanetary magnetic field strength and total solar irradiance. In late 2009, the cosmic ray intensity was at its highest level of the space age, coinciding with a record low in the interplanetary magnetic field (IMF). Correlated variations of cosmic rays with the IMF, and the IMF with total solar irradiance, enable Be-10 measured in ice cores to trace solar activity back over 10,000 years.

David Gubbins [School of Earth and Environment, University of Leeds] posed the question, *Internal Geomagnetic Fields on the Millennium Time Scale: Are We Going into Another Excursion?* Gubbins reported that the Earth's magnetic dipole moment is falling at the rapid rate of about 5% per century, prompting the question: are we about to have another *excursion*—when the geomagnetic field becomes weak and its direction wayward—or perhaps, less likely, a complete reversal? It is possible, although the present dipole moment is no weaker than the average over the last million years, so it has some way to go. However, this decrease will influence *geomagnetic weather* and possibly the atmosphere.

Robert McPherron [Institute of Geophysics and Planetary Physics, University of California at Los Angeles] discussed *Effects of Geomagnetic Reversals on Solar Wind-Magnetosphere Coupling*, explaining that the Earth's magnetic field is decreasing in strength at a rate that would bring it to zero in the next 1000 years, if it were to continue at the current rate. This decrease makes the magnetosphere smaller, increases the size of the polar caps, alters the access of energetic particles, and changes the way solar wind energy is dissipated in the atmosphere. If it is shown that this energy plays a role in climate change then the effects should be included in future models of this phenomenon. More important, these changes will alter the environment experienced by human assets in space and on the ground.

Charles Jackman [GSFC] provided an overview of several Energetic Particle Precipitation (EPP)-related important processes and their impacts on the stratosphere and mesosphere. EPP can have significant impacts on polar mesospheric and stratospheric chemistry and—possibly—circulation, providing a feasible pathway for Sun–climate coupling. Such impacts occur after solar eruptions or particular geomagnetic storms and can also be connected with unusual wintertime polar meteorology, which occurs even during times of low geomagnetic activity. Even though some EPP impacts occur impulsively over short periods of time after solar eruptions or particular geomagnetic storms, the most important impacts are caused by long-lived EPP-produced polar NO_y on timescales of months to years. This EPP-produced NO_y can then impact polar ozone, leading to significant decreases and increases.

Cora Randall [LASP, CU] continued on the theme of Energetic Particle Precipitation and spoke on *Atmospheric Coupling via Energetic Particle Precipitation*, which was a summary of current understanding of the middle atmosphere response to EPP. Randall highlighted some of the recent advances in this field, in particular, on vertical coupling in the polar regions, and the so-called *indirect effect* of EPP. In three of the last seven Arctic winters, extraordinary meteorology in Stratosphere-Mesosphere-Lower-Thermosphere regions led to unusually strong descent of air from the mesosphere into the stratosphere. In each of these three years (2004, 2006, 2009), the descent led to enhancements in polar NO_x mixing ratios that were larger than ever before recorded. These enhancements have been attributed to EPP even though, in 2006 and 2009, geomagnetic activity levels were lower than average. She described the observational evidence for this coupling, and put the results into the context of current modeling efforts.

Education and Public Outreach

Cherilynn Morrow [Department of Physics & Astronomy, Georgia State University] gave a very interesting talk on *Learning Theory and Practical Lessons from Experiences in Science Education Reform.* Morrow presented examples of misconceptions and misunderstandings related to Sun–Earth climate science and called for a more scholarly approach to science communication on the part of scientists, science educators, and other science communicators based in research about how people learn. Attributes of scholarly science instruction and science communication include misconception awareness; use of interactive engagement techniques; being vigilant about jargon and metaphors; relating stories about scientific investigations that make the nature of scientific inquiry explicit; and using effective communication techniques and strategies from fellow communicators.

John Katzenberger [AGCI—*Director*] gave a teacher's perspective on the Sun–Earth System. Katzenberger explained that over the past 50 years there has been a sporadic national effort to improve science education in the U.S. Much has been learned about how people learn and pedagogical approaches that work. However, this has not translated into better results: the U.S. performs below average compared to other Organisation for Economic Co-operation and Development (OECD) countries while spending more per student. These students become the citizens that perform poorly in surveys of basic science literacy and lack the necessary critical thinking tools to assess important environmental issues such as climate change. The science community could play a critical role in improving education and public outreach by becoming more actively involved. He also stated that this workshop has important implications for expanding the AGCI mission from *furthering the understanding of Earth system science and global environmental change to furthering the understanding of the Earth-Sun system and global environmental change.*

Rick Chappell [Vanderbilt University] gave the last talk in this session, speaking on *Communicating Global Change Science to the Public.* Chappell commented that science is tremendously important to the world but the media do not always communicate it well to the public, and furthermore, scientists do not always communicate it well to the media. Scientists must be proactive in explaining their science understandably to their "stakeholders." Stories of science are part of the narrative that forms our culture. These stories are not just about the results, but they are about amazing people doing amazing things. We must all share our *stories of exploration*!

Solar Variability and Influences

Jerry Harder [LASP, CU] presented recent analysis of data from the SORCE Solar Irradiance Monitor (SIM). Some spectral irradiance trends are larger than the solar modulations that compensate to produce the TSI trend and cannot be explained by solar active region evolution alone. Spectral observations from SIM suggest a very different response in the Earth's atmosphere than has been considered, requiring further modeling studies and analysis of existing atmospheric observations.

Jeff Hall [Lowell Observatory] was unable to attend so **Karel Schrijver** [Lockheed Martin Advanced Technology Center] presented Hall's paper, *Spectral and Brightness Variations of Cycling and Flat Activity Sun-Like Stars*. Hall explained that there is no dynamo model yet that can tell us *ab initio* how active a star will be, how it will vary in time, the statistics of emerging bipolar regions, or the eruptive/explosive processes. Although the Sun is in a characteristic dynamo state of the solar/stellar ensemble, stellar observations show a range of patterns that the Sun has not shown in the instrumental era.

Gregg Kopp [LASP, CU] showed the 32-year old total solar irradiance climate data record from which proxies are derived to build reconstructions of historical solar inputs to the Earth's climate system. Kopp pointed out that the accuracies of reconstructions depend upon the accuracy of irradiance data record itself, in addition to a number of other factors, such as the observational sunspot record, solar magnetic field propagation models, variability measurements of Sun-like stars, and heliospheric influences on cosmogenic isotopes. He derived the climate-driven requirements for total solar irradiance measurement accuracy and stability and discussed progress for improving this solar climate data record.

In his own presentation**, Karel Schrijver** showed that the Sun and stars exhibit many scale-invariant properties that appear insensitive to stellar fundamental properties. These relationships may be exploited in order to extrapolate the historical behavior of the Sun, predict its future, and characterize the variability of solar and space climate. He also explained that many solar/heliospheric records remain hidden in Earth's deposits of ice and sediments, containing information that is needed by solar/heliospheric physicists and climate physicists for long-term trend characterization.

Phil Chamberlin [GSFC] presented a paper on the 60-year reconstruction of the solar vacuum ultraviolet (VUV) spectrum (0.1–200 nm). Because observations of solar spectral irradiance are extremely limited on climate timescales, empirical models require solar proxies to reconstruct the output of the Sun over long-time scales. Chamberlin reviewed the Flare Irradiance Spectral Model (FISM), an empirical model of the solar VUV irradiance spectrum for use in ionospheric and thermospheric models.

Tom Woods [LASP, CU] put the recent solar minimum in the context of the longer record of solar variability. The recent solar cycle minimum that began in 2007 and lasted until 2009, was longer and exhibited lower irradiance, solar wind, and magnetic field than the last solar minimum that occurred in 1996. This latest minimum was similar to those in the early 1900s, a period known as the *Gleissberg Minimum*. Woods concluded that few studies relating how the Earth system responded to this low minimum have been completed. One study, however, on the thermosphere [*Emmert et al., GRL, 2010*] reported 28% less density at 400 km.

Solar Cycle/Atmosphere Effects

Dick White [LASP, CU] led a discussion on terrestrial climate history, stressing the urgency in understanding climate over the next 40 years. During this time, when it is expected that the Earth's population will reach nine billion people, understanding past climate stressors will become increasingly important. Climatic extremes due to glaciation and volcanoes in the distant past are important, but the most relevant epoch will be from Common Era (CE) 1000 to CE 1900. This timespan covers the best-recorded climate history of warming and cooling extremes.

Hauke Schmidt [Max Planck Institute for Meteorology] discussed *The Solar Cycle Effect in the MLT region - Simulations with the Hamburg Model of the Neutral and Ionized Atmosphere (HAMMONIA)*. Schmidt explained that the mesopause region reacts to solar cycle forcing by an increase in temperature. The amount of this increase simulated by HAMMONIA is 3–5 K from solar minimum to maximum while the observed changes vary from 0–10 K. The mesopause region reacts to other types of forcing and internal variability, making attribution of signals from short-time series difficult. He also stated that models and observations suggest that the summer mesopause region and winter stratosphere are strongly coupled dynamically. Therefore, the high-latitude mesopause shows a response not only to local forcing but also to forcing affecting the stratosphere. Accordingly, signals in the high-latitude mesopause are obscured by stratospheric variability.

Middle and Upper Atmosphere Effects

Jeff Forbes [Aerospace Engineering Sciences, University of Colorado] opened the session with his talk *Interannual Variability Due to the El Niño–Southern Oscillation (ENSO)*. He described the Earth's atmosphere from 0–500 km as a single connected system. Latent heating and other processes (e.g., heating by water vapor absorption), excite a spectrum of waves that carry amplified tropospheric signals throughout the atmosphere. Analysis of these signals can inform us about tropospheric processes and changes.

Maura Hagan [NCAR] followed with a discussion of anthropogenic and natural variability in the Earth's upper atmosphere. Hagan stated that variations in solar irradiance have profound effects on Thermosphere–Ionosphere system temperatures and densities. We need to gain a better understanding of the altitudinal structure and variability of thermospheric winds on multiple horizontal and temporal scales.

Jim Russell [Atmospheric and Planetary Sciences, Hampton University] presented an overview of space-based observations of Polar Mesospheric Clouds (PMCs) and scientific implications of data primarily from the Aeronomy of Ice in the Mesosphere (AIM) mission, the first mission dedicated to the study of PMCs. PMCs exhibit a great deal of orbit-to-orbit and day-to-day variation and have significant complex structure. Planetary waves modulate PMC occurrence and can effectively extend the PMC season by providing several days of localized regions of saturated air in the troughs of the waves. By contrast, gravity waves appear to locally diminish PMC frequency even though global scale gravity wave drag is acknowledged as the prime cause of the cold polar summer mesopause. Satellite results also provide evidence that interhemispheric coupling, from the winter hemisphere to the summer hemisphere affects PMC variability.

Victor Pasko [Department of Electrical Engineering, Pennylvania State University] concluded the session with his talk, *Lightning-related Transient Luminous Events at High Altitude in the Earth's Atmosphere*. Pasko discussed the phenomenology and physical mechanisms of lightning-related transient luminous events in the middle atmosphere called *sprites*, *jets*, and *elves*. He reviewed possible effects and relationships of these energetic events to atmospheric infrasonic emissions, global electric circuit, and terrestrial gamma ray flashes. The history of observations of these events is relatively short. Although there are some data already available indicating that very large quantities of charge can be moved to the lower ionosphere in association with these events, their effects on the global electric circuit remain to be quantified.

Walter Orr Roberts Memorial Public Lecture

On the evening of June 15, **Tom Woods** [LASP, CU] gave a public lecture, entitled *Our Dynamic Sun and How its Changes Affect Earth*. The lecture highlighted NASA's recently launched Solar Dynamics Observatory, including the spectacular new high-resolution imagery of the full solar disk.

Workshop Conclusion/Discussion

The presenters were asked to provide two major points from their talks, much of which provided the basis for this summary. All attendees participated in a discussion on *what we know and what we don't know*, a lively exchange intended to crystallize thoughts on the current state of knowledge of global change and the solar-terrestrial environment, and where the greatest challenges lie in improved understanding and potential societal benefits to be gained. Further discussions on *Synthesis and Outcomes* ensued, some of which will be represented in a forthcoming *Eos* paper inspired by the workshop discussions. ■

GOES-13 Satellite Captures Powerful Snowmaker Leaving New England

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On December 27, 2010, snows were finally winding down in New England as a powerful low pressure system brought blizzard conditions from northern New Jersey to Maine over the Christmas weekend. The Geostationary Operational Environmental Satellite (GOES-13) captured dramatic images of the storm. GOES satellites are operated by the National Oceanic and Atmospheric Administration, and NASA's GOES Project, located at NASA's Goddard Space Flight Center, creates some of the GOES satellite images and animations.

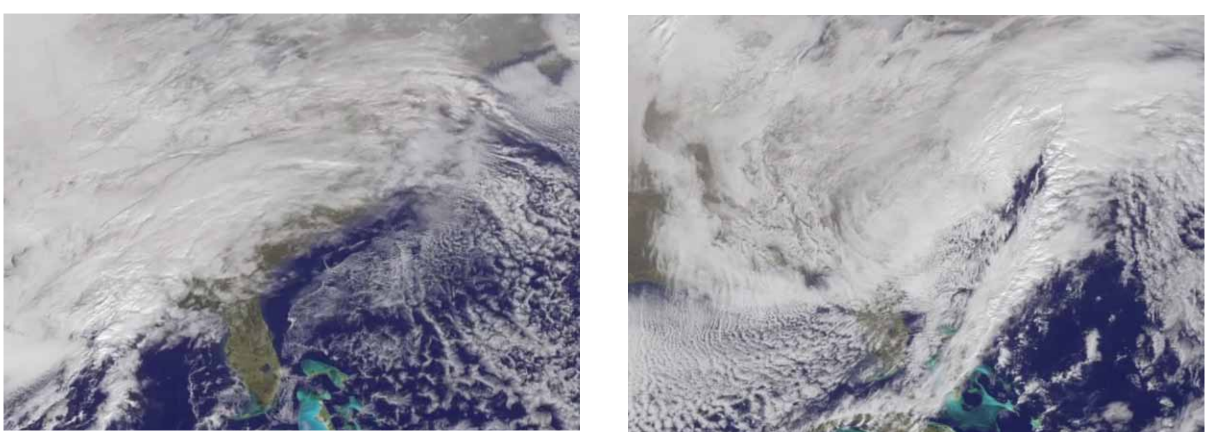
As of 1:30 PM EST, all Blizzard Warnings were canceled as the low had pulled much of its snow and rain away from land areas and into the North Atlantic Ocean but the winds behind the system were causing more problems for residents along the U.S. East Coast.

In Atlanta, GA snowfall ranged from 1.5 in to more than a foot in various areas of New Jersey, New York, and the New England states. More than 11 in of snow was reported near Wallops Island, VA—where NASA has a facility. Newark, NJ reported 17.7 in of snow by midnight on December 26. Central Park in New York City reported 12.0 in of snow had fallen just before midnight. Providence, RI reported 7.9 in by midnight, while Boston, MA reported 9.9 in at that time. More snow fell on top of those totals during the morning hours the following day.

Some of those snows are visible in the GOES-13 satellite image from December 27. The image shows snow over South and North Carolina, Virginia, Maryland, Delaware, Eastern Pennsylvania, New Jersey, and Southeastern New York. The clouds of the low obscure New England.

On Monday, December 27 at 1731 UTC (12:31 PM EST), the GOES-13 satellite captured this visible image of the powerful low pressure system that brought snows from Georgia to Maine along the U.S. east coast. Some of the snowfall can be seen over South and North Carolina, Virginia, Maryland, Delaware, Eastern Pennsylvania, New Jersey, and Southeastern New York. The clouds of the low obscure New England in the image. **Credit:** NOAA/NASA GOES Project

From Maine south to the Carolinas winds howled in excess of 30 mph, and power outages were reported as a result of the winds in the areas with the heaviest snows. The winds in Portland, ME on December 27 are blowing from the northwest from 20–30 mph with gusts over 40 mph. The day before in Newark, NJ sustained winds of 41 mph were reported with gusts as high as 51 mph. Going further south, the Raleigh, NC National Weather Service office noted that sustained northwest winds of 10–20 mph with gusts up to 30 mph were expected. Even further south, Atlanta, GA experienced winds up to 20 mph. The winds made clean-up efforts difficult along the East Coast. ■



Recipe for the Christmas Blizzard of December 25–27, 2010: Pour arctic air down the Mississippi, across the Gulf, and then up the East Coast—keep the atmosphere stirred, not shaken. These video stills come from an animation that was created using images from the GOES series of satellites. GOES satellites are operated by NOAA and the animation was created by the NASA GOES Project at NASA Goddard Space Flight Center. To view the animation, please visit: *www.nasa.gov/centers/goddard/news/features/2010/goes13-snow.html.* **Credit:** NASA/Goddard Space Flight Center

NASA's Terra Satellite Sees a Snow-Covered Ireland

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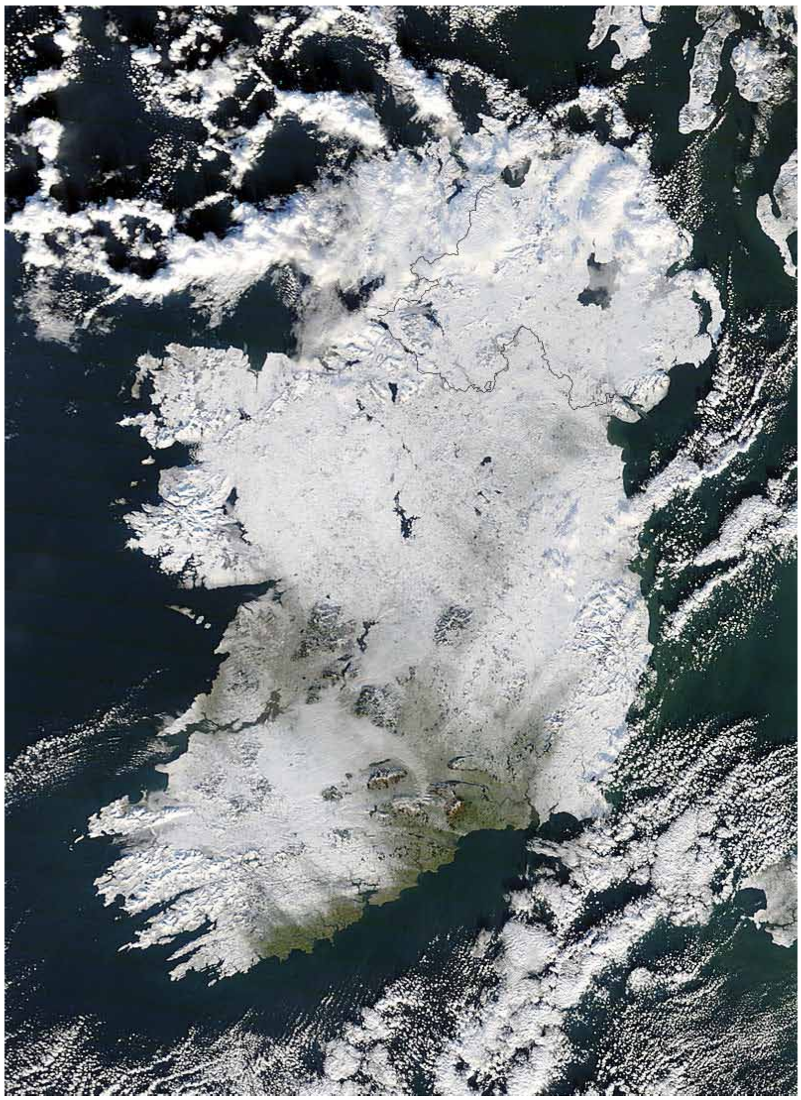
The Mid-Atlantic and Northeastern U.S. were not the only areas that dealt with holiday snowfall. Ireland was swathed in white on December 22, 2010—the Emerald Isle has been unusually white this winter. When NASA's Terra satellite passed overhead, the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument captured an image of the snow. The overnight arrival of 6 in (15 cm) of snow at the Dublin airport forced its closure. Combined with the closure of the City of Derry airport, travel became quite difficult.

MODIS images are created by the MODIS Rapid Response Team at NASA's Goddard Space Flight Center. The MODIS instrument flies onboard NASA's Terra and Aqua satellites.



The Emerald Isle was swathed in white on December 22, 2010, when the MODIS instrument aboard the Terra satellite passed overhead, capturing this true-color image. **Credit:** NASA Goddard/MODIS Rapid Response Team, Jeff Schmaltz

Ireland enjoys a "temperate ocean climate," a Cfb classification based on the Koopen climate classification system. Such climates normally enjoy cool, cloud-covered summers and mild winters. Ireland's climate is also moderated by the warm waters of the Gulf Stream, which flows off the western shore. Snow commonly falls only in the highest elevations; dustings may occur elsewhere a few times each year. Significant accumulations anywhere in the country are rare.

The winter of 2009-2010 was unusually cold and snowy. Called "The Big Freeze" by the British media, it brought widespread transportation problems, school closings, power failures, and twenty five deaths. A low of -8.1°F (-22.3°C) was recorded on January 8, 2010, making it the coldest winter since 1978–79.

It's not over yet but already, the winter of 2010-2011 threatens to be just as challenging. The earliest widespread snowfall since 1993 occurred on November 24, primarily affecting Great Britain and Scotland. Two days later snow began to cover Ireland, and the continuing severe weather has taken a toll. It has disrupted air, road and rail travel, closed schools and businesses, and caused power outages. Livestock and horses have had difficulty finding grass to eat, some relying on volunteer feeding efforts for survival. Local temperature records were broken, including a new record low for Northern Ireland of -2°F (-18.7°C) at Castlederg on December 23. As of that date, 20 deaths had been attributed to the winter weather and associated hazards. ■

Mexico Quake Studies Uncover Surprises for California

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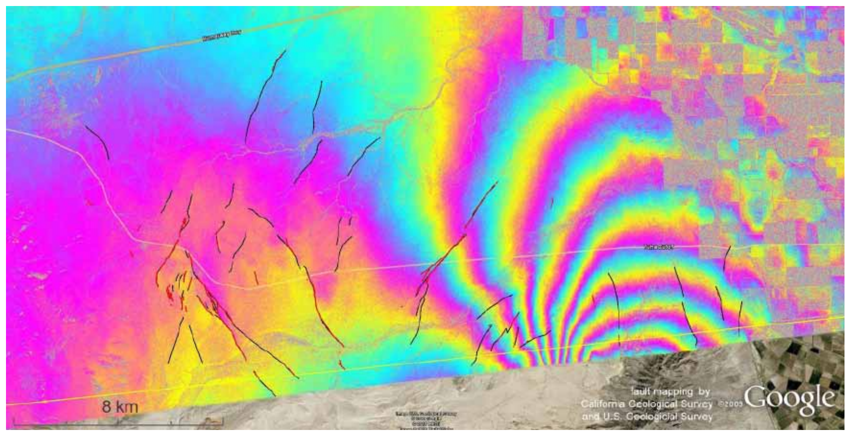
New technologies developed by NASA and other agencies are revealing surprising insights into a major earthquake that rocked parts of the American Southwest and Mexico on April 4, 2010—including increased potential for more large earthquakes in Southern California.

At the fall meeting of the American Geophysical Union in San Francisco, scientists from NASA and other agencies presented the latest research on the magnitude 7.2 El Mayor–Cucapah earthquake, that region's largest in nearly 120 years. Scientists have studied the earthquake's effects in unprecedented detail using data from GPS, advanced simulation tools, and new remote sensing and image analysis techniques. These techniques include airborne lidar, satellite synthetic aperture radar, and NASA's airborne Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR).



Interpreted faults from UAVSAR. This UAVSAR image, covering the time period from October 21, 2009–April 13, 2010, shows ground deformation that is largely a result of the April 4, 2010 earthquake in Baja CA. **Credit:** NASA JPL/USGS/California Geological Survey/Google

Among their findings:

- The earthquake is among the most complex ever documented along the Pacific/North American tectonic plate boundary. The main shock activated segments of at least six faults—some unnamed or previously unrecognized. The quake triggered *slip* along faults north of the border as far as 100 mi (about 161 km) away, including the San Andreas, San Jacinto, Imperial, and Superstition Hills Faults, as well as many faults in California's Yuha Desert, some not previously mapped. Some of this slip was quiet, without detectable earthquakes. Activity was observed on several northwest-trending faults due for potentially large earthquakes.

- The rupture's northern end in Southern California resembles the frayed end of a rope. The complex, 20-mi (32-km) network of faults that slipped there during and after the earthquake—many unnamed or previously unrecognized—reveals how the earthquake distributed strain.

- Satellite radar, UAVSAR and GPS station data show additional *slip* along some of the Yuha Desert faults in the months after the main earthquake. Recent data from UAVSAR and satellite radar show this slip slowed and probably stopped in late summer or early fall.

- Mexico's Sierra Cucapah mountains were, surprisingly, lowered, not raised, by the earthquake.

- The main rupture jumped an 7-mi (11-km) fault gap-more than twice that ever observed before.

- UAVSAR and satellite radar reveal deep faulting that may be a buried continuation of Mexico's Laguna Salada Fault that largely fills the gap to California's Elsinore Fault. This could mean the fault system is capable of larger earthquakes. A connection had only been inferred before.

- Analyses show a northward advance of strain after the main shock, including a pattern of triggered fault slip and increased seismicity. The July 7, 2010 magnitude 5.4 Collins Valley earthquake on the San Jacinto Fault may have been triggered by the main earthquake.

- Forecasting methods in development suggest earthquakes triggered by the main shock changed hazard patterns, while experimental virtual reality scenarios show a substantial chance of a damaging earthquake north of Baja within three to 30 years of a Baja quake like the one in April.

"This earthquake is changing our understanding of earthquake processes along the Pacific/North American plate boundary, including earthquake physics, forecast modeling and regional faulting processes," said **John Fletcher** of the Center for Scientific Research and Higher Education at Ensenada (CICESE), Baja CA, Mexico. Fletcher led a multi-agency Mexico fault mapping effort that included the U.S. Geological Survey and California Geological Survey, among others.

UAVSAR, developed by NASA's Jet Propulsion Laboratory, uses a technique called interferometric synthetic aperture radar to measure ground deformation over large areas to a precision of 0.04–0.2 in (0.1–0.5 cm). A NASA *Gulfstream III* aircraft carrying the radar flew repeat GPS-guided passes over the California border region twice in 2009 and four times since the April earthquake, imaging the area in the immediate aftermath of the quake and monitoring continuing deformation since. Field mapping since April has demonstrated its ability to show remarkable surface rupture detail.

"UAVSAR is blanketing California's seismic danger zones about every six months to detect changes such as earthquakes or creeping faults," said JPL Geophysicist **Eric Fielding**. "The major earthquake in Baja last April is providing direct evidence that time-critical monitoring of hazardous faults is possible through NASA-funded technology."

"The accurate and detailed imagery derived from synthetic aperture radar, and in particular UAVSAR, produced a more complete picture of fault patterns, precisely guiding field geologists to remote areas of fault rupture and saving significant mapping time," said geologist **Jerry Treiman** of the California Geological Survey, Los Angeles.

JPL geophysicist **Jay Parker** said UAVSAR's precise images are adding realism to NASA's *QuakeSim* crustal models and forecasts. "Once we have these precise measurements of the changing landscape, we use them to deduce changes in stress that accelerate or delay the next major earthquakes, with the help of structural models and forecasting tools," he said.

For more on UAVSAR, see: *uavsar.jpl.nasa.gov/*. For more on *QuakeSim*, see: *quakesim.jpl.nasa.gov/*. ■

The photo shows a surface rupture on the Borrego Fault produced during the El Mayor-Cucapah earthquake that struck northern Baja California on April 4, 2010. Geologists measuring the displaced channel bottom have discovered that approximately 3 meters of surface displacement occurred on this segment of the rupture. From left to right, the geologists working in the crevase are **Ronald Spelz**, **Eulalia Masana**, and **Tom Rockwell**. **Image credit:** John Fletcher

EOS Scientists in the News

Kathryn Hansen, NASA Earth Science News Team, khansen@sesda2.com

Tracking the Gulf of Mexico Oil Spill from Space, November 8; *EarthSky*. **Michael Goodman** (NASA MSFC) explained how NASA satellites monitored the progression of the Gulf of Mexico oil spill in 2010, from the initial blowout on April 20 and throughout the summer months, May-June-July, as the oil slick spread and impacted the coastal ecosystems along the Gulf coast.

Meltwater from Glaciers Could Warm Ice Even More, November 9; *Our Amazing Planet.* Researchers at the Colorado Center for Astrodynamics Research developed a model to show that meltwater flowing through cracks in glaciers and ice sheets spends more time inside the ice than scientists realized; **Tom Neumann** (NASA GSFC) said the new model introduces a possible mechanism to explain how changes in surface temperature can affect temperatures deep inside thick ice.

How's Antarctica Faring? Experts Fly Over Ice to Find Out, November 15; MSNBC. Now in its second year, *Operation IceBridge* has been measuring ice at Earth's poles; **Michael Studinger** (NASA GSFC/UMBC), **Chris Shuman** (NASA GSFC/UMBC), and **Seelye Martin** (University of Washington) described the research flights over Antarctica during the 2010 field season.

A Glory-Ous Rainbow Over Antarctica, November 18; *Our Amazing Planet.* In an image taken October 26 by **Michael Studinger** (NASA GSFC) over Antarctica's Brunt Ice Shelf, a glory surrounds the shadow of the DC-8 plane that is flying NASA's *Operation IceBridge* mission to survey the state of Antarctic ice; the image was taken during the first flight of IceBridge's Fall 2010 campaign.

NASA Says Earth's Lakes are Warming, November 23; *Agence France-Presse.* The Earth's largest lakes have warmed up over the past 25 years in response to climate change, according to a study by **Philipp Schneider** (NASA JPL) and **Simon Hook** (NASA JPL), who used satellite data to measure the surface temperature of 167 lakes around the world.

As Hurricane Season Ends, Storm Studies Just Beginning, November 29; *Our Amazing Planet.* The Atlantic hurricane season officially ended November 30, but where hurricane season ends, years of work are just beginning for NASA researchers including **Scott Braun** (NASA GSFC) who spent the 2010 season flying a fleet of planes into storms.

Satellite Images Vital to Climate Negotiations, December 6; *EarthSky.* **Doug Morton** (NASA GSFC) talked about how images taken by the Landsat satellite were used as the scientific basis for an agreement under negotiation at the U.N. Climate Change Conference in December 2010.

More Plant Growth Could Slow Global Warming, December 7; *Agence France-Presse.* In a world with twice as much carbon dioxide in the atmosphere, plants could grow larger and create a cooling effect on a warming globe, according to a new study led by **Lahouari Bounoua** (NASA GSFC).

Retreating Mountain Glaciers Pose Freshwater Shortage, December 8; *Scientific American.* Climate's influence on Himalayan glaciers is still a looming concern for many scientists and governments. They worry about how warming will affect the region's water cycle; **William Lau** (NASA GSFC) said his research suggests black carbon could rival greenhouse gases as a cause of warming in the Himalayas.

Aqua Satellite Data Improves Weather Forecasts and Models, December 13; *EarthSky.* **Ron Gelaro** (NASA GSFC) described efforts to predict weather across the globe using computer simulations that incorporate measurements form NASA's Aqua satellite.

Antarctic Sea Ice Melting as Ocean Heat Rises, December 14; *Discovery News.* How fast West Antarctic ice will melt and in what locations depends largely on whether upwelling warm water comes in contact with the thick ice shelf that crowds the coast and blocks the glaciers from reaching the sea, which in turn depends on the winds which drive away the surface waters and make it possible for the deeper waters to rise to the surface, said **Robert Bindschadler** (NASA GSFC/UMBC).

Puzzle of Antarctic Ice Melt Solved, December 15; *Our Amazing Planet.* **Ted Scambos** (NSIDC), **Bob Bindschdler** (NASA GSFC/GEST), and **Michael Studinger** (NASA GSFC/GEST) presented new findings at the fall meeting of the American Geophysical Union that revealed new pathways for ice loss in West Antarctica.

Report: Humanity 'Pushing' Plant Resources, December 16; *United Press International.* **Marc Imhoff** (NASA/GSFC) reported at the fall meeting of the American Geophysical Union that from 1995–2005, human consumption of land plants rose from 20% to 25% of Earth's total plant production each year.

Mother Nature Pulls a Fast One on Forecasters, December 21; *Los Angeles Times.* The Los Angeles Basin has gone from a cool summer to a record hot day in the fall and is headed for the wettest December on the books, and experts say, there are no easy explanations. Among those experts is **Bill Patzert** (NASA JPL), who says in general, as the globe warms, weather conditions tend to be more extreme and volatile.

Forecasters: California Should See Drier Winter, December 23; *Associated Press.* California should experience a drier than average winter thanks to the La Niña climate phenomenon, despite the December storm system that was caused by cold polar air clashing with warm, moist air to create the wild weather, said **Bill Patzert** (NASA JPL).

NASA's Bob Benson: Tales of Chilly Research, December 30; *Red Orbit.* **Bob Benson** (NASA GSFC) is a one-person historical record of ionospheric studies at NASA and even beyond, and his research has taken him from pioneering Antarctic campaigns with supplies air-dropped in, to years in the wilds of Alaska, and finally back to an office to archive and rescue some of the earliest data from this field.

Interested in getting your research out to the general public, educators, and the scientific community? *Please contact Kathryn Hansen on NASA's Earth Science News Team at khansen@sesda2.com and let her know of your upcoming journal articles, new satellite images, or conference presentations that you think the average person would be interested in learning about.* ■

NASA Names Waleed Abdalati as Agency's New Chief Scientist

NASA Administrator **Charles Bolden** has named **Waleed Abdalati** the agency's chief scientist, effective January 3, 2011. Abdalati will serve as the principal adviser to the NASA administrator on agency science programs, strategic planning, and the evaluation of related investments.

Abdalati is currently the director of the Earth Science and Observation Center at the University of Colorado at Boulder, and an associate professor in the university's geography department. From 1998–2008, Abdalati held various positions at NASA in the areas of scientific research, program management, and scientific management. His research focuses on the study of polar ice cover using satellite and airborne instruments, how and why the Earth's ice cover is changing, and what those changes mean for life on our planet. He has led or participated in nine field and airborne campaigns in the Arctic and the Antarctic.

Abdalati will represent all the scientific endeavors in the agency, ensuring they are aligned with and fulfill the administration's science objectives. He will advocate for NASA science in the context of broader government science agendas and work closely with the White House Office of Science and Technology Policy and the Office of Management and Budget.

"We are excited to have Waleed return to the agency during such a critical transition period," Bolden said. "His experience, wide-range of scientific knowledge and familiarity with NASA will greatly benefit the agency. He will be a true advocate for our many and diverse science research and exploration programs."

During his first tenure at NASA, Abdalati served as the head of the Cryospheric Sciences Branch at Goddard Space Flight Center. He also managed the Cryospheric Sciences Program at NASA Headquarters.

Abdalati received a Bachelor of Science in mechanical engineering from Syracuse University, a Master of Science in aerospace engineering sciences from the University of Colorado, and a doctorate in geography from the University of Colorado. He has published more than 50 peer-reviewed papers, book chapters, and NASA-related technical reports. His numerous awards include the Presidential Early Career Award for Scientists and Engineers, a NASA Exceptional Achievement Medal, and two NASA Group Achievement Awards.

The *Earth Observer* staff and the scientific community congratulate Abdalati on this tremendous accomplishment!

(Text modified from a NASA Headquarters Office of Communication notice)

NASA Science Mission Directorate – Science Education Update

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Online Climate Change Course for Advanced High School Students to Professionals
(Beginning March 2011)

The State University of New York's College of Environmental Science and Forestry is offering an online course on climate change. *Climate Change Science and Sustainability* is a one-credit, six-week online course that introduces participants to climate science, the evidence of modern climate change, and an evaluation of some of the proposed solutions. The course is taught by veteran meteorologist **Dave Eichorn** (American Meteorological Society) and integrates NASA and other web-based climate-change media with outside readings. NASA's spatial and temporal climate change resources are the basis for most learning activities, and enable students to continue their exploration of climate change after completion of a course. Climate Change Science and Sustainability runs March 21–May 6. For more information about the course and to register, visit: *www.esf.edu/esfonline.*

2011 Thacher Environmental Research Contest for Grades 9-12 (**Deadline:** April 11, 2011)

From the massive Gulf oil spill to the continued decline of Arctic sea ice, NASA satellites and other observing instruments proved crucial last year in monitoring the many environmental changes—both natural and human-induced—occurring on global, regional, and local scales. The 2011 Thacher Environmental Research Contest, sponsored by the Institute for Global Environmental Strategies, challenges high school students (Grades 9-12) to conduct innovative research on our changing planet using the latest geospatial tools and data.

The best projects will receive cash awards in the amount of $2,000 for first place; $1,000 for second place; and $500 for third place. Individuals or teams of up to four students may submit entries. In the case of team entries, the cash award will be split equally among the winning team members. Winners will also be featured in an *Encyclopedia of the Earth* article. In addition to the student prizes, teachers or adult "coaches" of the first-, second-, and third-place students will receive a $200 *Amazon.com* gift card. For more information, visit: *www.strategies.org/thachercontest.*

Online NASA-Funded Lab Earth Courses Available Spring 2011

Two NASA-funded courses will be offered through the University of Nebraska's Masters of Applied Science program. **NRES 898:** *Human Dimensions in Climate Change* offers a practical understanding of the concepts and applications of the Geographical Information Systems (GIS), Global Positioning Systems (GPS), and Remote-sensing Technologies. **NRES 814:** *Laboratory Earth: Earth's Natural Resource Systems* applies fundamental concepts in the Earth and physical sciences to understanding Earth's natural resource system. Each three-credit-hour course may be taken independently, or as part of the Masters of Applied Science Online Degree for Science Educators. For more information, visit: *onlinegrad.unl.edu/programs/masters/science.*

NASA EDGE Live@A-Train Symposium Vodcast

The NASA EDGE vodcast, recorded at the A-Train Symposium, features interviews with scientists discussing the A-Train. The information presented includes discussion of the Earth observing satellites that compose (or will compose) the A-Train [Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), CloudSat, Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL), Aqua, Aura, Orbiting Carbon Observatory (OCO-2), Glory, and Global Change Observation Mission-Water (GCOM-W1)], as well as discussion on what information is being collected and how that information is used to study Earth's climate. To view the vodcast, please visit: *www.nasa.gov/multimedia/podcasting/nasaedge/NE00111910_L07_A-Train.html.*

Aerosols: Tiny Particles, Big Impact

This resource from NASA's Earth Observatory features background information on aerosols, their effect on Earth's climate, images and maps showing the distribution of aerosols worldwide, and information on how aerosols are measured. To access, please visit: *earthobservatory.nasa.gov/Features/Aerosols/page1.php.* ■

EOS Science Calendar

March 1–3, 2011
Landsat Science Team Meeting, Phoenix, AZ.

March 8–10, 2011
SMAP Science Definition Team (SDT) Meeting #6, Pasadena, CA. URL: *smap.jpl.nasa.gov/science/workshops/*

March 28–April 1, 2011
Atmospheric System Research (ASR) 2011 Science Team Meeting, San Antonio, TX. URL: *asr.science.energy.gov/meetings/stm/*

April 26–28, 2011
CERES Science Team Meeting, Newport News, VA. URL: *ceres.larc.nasa.gov/ceres_meetings.php*

April 26–29, 2011
NASA Sounder Science Team Meeting, Caltech Beckman Institute Auditorium, Pasadena, CA. URL: *airs.jpl.nasa.gov/meetings/science-team-pasadena/*

May 3–5, 2011
SMAP Cal/Val Workshop #2, Oxnard, CA. URL: *smap.jpl.nasa.gov/science/workshops/*

September 13-16, 2011
SORCE Science Meeting: Symposium on the Decadal Variability of Earth's Climate, Solar Irradiance, and Sun-like Stars, Sedona, AZ. URL: *lasp.colorado.edu/sorce news/2011ScienceMeeting/index.html*

Global Change Calendar

March 27–31, 2011
American Chemical Society Spring Meeting. Anaheim, CA. URL: *portal.acs.org/portal/acs/corg/content*

April 10–15, 2011
34th International Symposium on Remote Sensing of Environment (ISRSE): The GEOSS Era: Towards Operational Environmental Monitoring, Sydney, Australia. URL: *isrse34.org/*

May 1–5, 2011
American Society for Photogrammetry and Remote Sensing 2011 Annual Conference, Milwaukee, WI. URL: *www.asprs.org/milwaukee2011/*

May 16–19, 2011
Year of Tropical Convection (YOTC) International Science Symposium and 8th Asian Monsoon Years (AMY) International Workshop, Beijing China. URL: *yotc-amy-2011.csp.escience.cn/dct/page/1*

June 21–24, 2011
Annual Air and Waste Management 104th Annual Conference and Exhibition, Orlando, FL. URL: *www.awma.org/ACE2011/*

June 27–July 8, 2011
XXV International Union of Geodesy and Geophysics General Assembly: Earth on the Edge: Science for a Sustainable Planet, Melbourne, Australia. URL: *www.iugg2011.com*

July 10–15
Gordon Research Conference: Clouds, Aerosols, Precipitation and their Role in Climate and Climate Change, Colby College, Waterville, ME. URL: *www.grc.org/programs.aspx?year=2011&program=radclimate*

August 1–5, 2011
2011 IEEE International Geoscience and Remote Sensing Symposium, Sendai, Japan. URL: *igarss11.org/*

August 30–September 1, 2011
GEWEX Radiation Panel (GRP) Meeting (by invitation), Tokyo, Japan.

October 24–28, 2011
World Climate Research Programme Open Science Conference, Denver, CO. URL: *www.wcrp-climate.org/conference2011/*

December 5–9, 2011
American Geophysical Union Fall Meeting, San Francisco, CA. URL: *www.agu.org/meetings/*

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