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The Earth Observer

Editor's Corner

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I'm pleased to announce that, after several unsuccessful attempts, the CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) missions were successfully launched aboard a Delta-II rocket from Vandenberg Air Force Base in California at 10:02 UTC on April 28. Each spacecraft will transmit pulses of energy and measure the pulses scattered back to the satellite. CloudSat's Cloud-Profiling Radar is more than 1,000 times more sensitive than typical weather radar. It can detect clouds and distinguish between cloud particles and precipitation. CALIPSO's polarization lidar can detect aerosol particles and distinguish between aerosol and cloud particles. Lidar, similar in principle to radar, uses reflected light to determine the characteristics of the target area.

Sixty-two minutes after liftoff, CALIPSO separated from the rocket's second stage. CloudSat followed 35 minutes later. Ground controllers successfully acquired signals from both spacecraft, and initial telemetry reports show both in excellent health. Over the next six weeks, system and instrument checks will be performed, and

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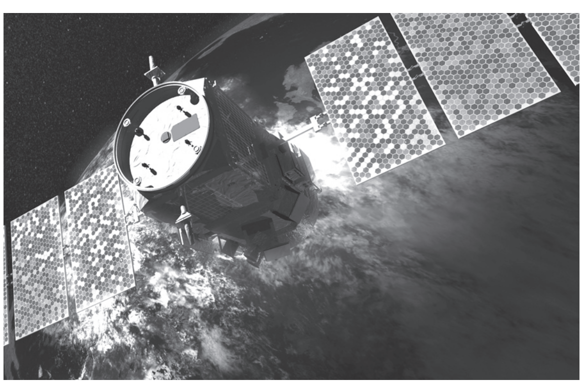
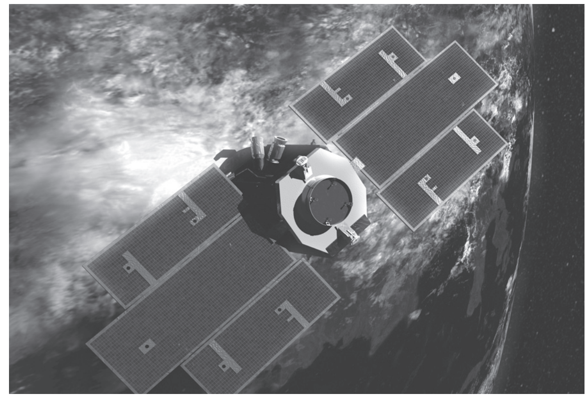
At 10:02 UTC on April 28, 2006, CloudSat/CALIPSO roared into orbit from Vandenberg Air Force Base in California aboard a Delta II rocket. These new NASA missions will further reveal secrets of clouds and aerosols and hopefully lead to new insights that will improve weather forecasting and climate prediction. Image courtesy: Boeing/Thom Baur

In This Issue



An illustration of CALIPSO on orbit image courtesy: NASA

the satellites will assume their final position in NASA's *A-Train* constellation, which already includes NASA's Aqua and Aura satellites and a French Centre National



An illustration of CloudSat on orbit image courtesy: NASA

d'Etudes Spatiale (CNES) satellite mission called Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL), and could eventually include NASA's planned Orbiting Carbon Observatory (OCO) mission. The combined information available from all of these satellites flying in formation is greater than what would be available if each mission flew independently, and should provide new insights into the global distribution and evolution of clouds to improve weather forecasting and climate prediction. For more information about CloudSat and CALIPSO, visit: *www.nasa.gov/cloudsat* and *www.nasa.gov/calipso.*

I'd also like to report that the Constellation Observing System for Meteorology (COSMIC) constellation of six satellites was successfully launched from Vandenberg Air Force Base at 9:40 PM EDT Friday, April 14, 2006. This network of satellites, using signals from the Global Positioning System (GPS), will provide real-time, 24-hour atmospheric data over thousands of locations on Earth for research and operational weather forecasting. It will help improve many areas of storm prediction including forecasting hurricanes and typhoons. This is of great interest to the meteorological community because it will provide temperature and moisture soundings for the Joint Center on Satellite Data Assimilation (JCSDA) and other National Meteorological Centers. COSMIC resulted from an agreement between the American Institute in Taiwan and the Taipei Economic and Cultural Representative Office in the U.S. It is based on a system design by the University Corporation for Atmospheric Research (UCAR), and was launched by NASA.

Unfortunately even as some missions begin, others come to an end. I'm sad to announce that as of March 6, 2006, the work of the METEOR-3M N1 spacecraft—with the Stratospheric Aerosol and Gas Experiment (SAGE III) onboard—was terminated. SAGE III, planned for a 3-year mission, successfully operated for 4 years and 3 months. The termination was caused by a power-supply system failure resulting in the loss of communication with the satellite. Despite the loss, the Russian Space Agency considers the joint U.S/Russian mission a success, and a good basis for future joint collaboration between the two countries. I would like to take this opportunity to thank everyone who participated in the METEOR-3M/SAGE III mission and wish them all the best.

In particular, I would like to recognize the retirement of **William Chu,** SAGE III Project Scientist, from NASA Langley Research Center. (Coincidentally, Chu's retirement took effect the same week that contact with SAGE III was lost.) Chu's research focused on the design and development of instruments and retrieval algorithms for the remote sensing of the middle atmosphere. He has been a central figure in the development and operation of the highly successful series of NASA-developed Solar Occultation sensors, which began in 1975 with the technology-demonstration flight of the Stratospheric Aerosol Measurement (SAM) mission on Apollo-Soyuz and then continued with the launch of SAM II (Nimbus 7), SAGE (AEM-2), SAGE II (ERBS), and SAGE III (METEOR-3M N1). Observations from these missions provide insight into the evolution of stratospheric aerosols and long-term behavior of stratospheric ozone. Chu is a member of the American Geophysical Union and the Optical Society of America. He has been a recipient of NASA's Exceptional Scientific Achievement Medal, Exceptional Service Medal, and Space Act Award. Chu earned his BS degree in Physics from Brooklyn Polytechnic Institute in 1965, and his PhD degree in Physics from the University of Rochester in 1970, and has been part of NASA Langley Research Center's Radiation and Aerosols Branch since 1977. I would like to congratulate Chu on his retirement after almost 30 years at NASA Langley and extend my personal thanks to him for his years of service as Project Scientist for SAGE III.

With regard to ongoing missions, I would like to congratulate the Ice, Clouds, and Land Elevation Satellite (ICESat) team on the successful completion of another 33-day operations campaign in February/March. A NASA P3 taking part in the *Arctic'06* field experiment did an underflight of several ICESat tracks over the Arctic sea ice. The team also got a successful flight of the P3 under both ENVISAT and ICESat while ICESat was passing over thicker ice on its way to Greenland. The next operations campaign is planned for late May and June.

I'm also pleased to report that *Geophysical Research Letters* recently compiled a special issue focusing on results from ICESat (Volume 32, Number 21, November 2005). In addition, NASA HQ has recently announced the members of the new ICESat Science Team. There were a total of 19 proposals selected: 4 for ice sheets, 2 for sea ice, 3 for atmospheres, 3 for terrestrial ecology, 2 for hydrology, 4 for solid Earth and geodesy, and 1 for oceans. Bob Schutz (University of Texas Center for Space Research) was selected to continue as Team Leader. Of the 19 proposals, 7 were submitted from researchers at GSFC, 2 from JPL, 1 from Langley, and 9 from Universities. The selections, along with abstracts can be viewed at: *nspires.nasaprs.com/external/viewrepositorydocument/39561/ICESat05%20Selections.pdf.*

In addition, *IEEE Transactions on Geoscience and Remote Sensing* has released a special issue focusing on Aura (Volume 44, Number 5, May 2006). This issue contains an overview paper on the Aura mission as well as overview papers for the MLS, OMI, and TES instruments. Other papers in the issue focus on instrument performance, calibration, algorithms, and data systems. Several of these show early results from Aura and demonstrate the successful performance of the mission.

I would also like to announce that, on April 21, the U.S. Geological Survey (USGS) put out a Request for Proposals to establish eight research and development contracts with highly qualified scientists and engineers that collectively will become the external members of the Landsat Data Continuity Mission (LDCM) Landsat Science Team, and who will conduct research pertinent to the LDCM. The award range per proposal will not exceed $100,000 per year per contract and the expected duration of each contract will be one base year and four option years. This will ensure science team continuity from the pre-launch planning period through the first operational year of the LDCM mission. Proposals are due by June 2. To view the full text of the solicitation, please visit: *ideasec.nbc.gov/j2ee/solicitationdetail.jsp?objId=810918&serverId=GS1434HQ,* and click on *Clauses and Attachments* in the upper left corner.

More recently, the USGS released a companion solicitation for participation by U.S. Federal Government and International Investigators on the LDCM Science Team. Up to eight scientists will be selected through a competitive process for a five-year period to contribute advice based on pertinent research and experience. "Those selected must demonstrate financial support from their home agency or organization since USGS contracting policies preclude funding salaries for Federal Government and International expert scientists." Five-page proposals are due by June 9. The full solicitation can be found at *ldcm.usgs.gov/documents/LST_Federal_International_Members.pdf*

In further LDCM developments, on May 11, an option for thermal observations was added to the original RFP in the form of a draft *Thermal Band Option Addendum to the "Imagery Requirements.* It can be found at *ldcm.nasa.gov/procurement/TIRimagereqs051006.pdf.*

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Satellite Data and Applications for the Next Generation Air Transportation System

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Introduction

Almost everyone has been inconvenienced by delayed or cancelled air travel. This is most often due to inclement weather conditions. With the air transportation system expected to triple in size by the year 2025, operational analysis models have shown that these delays and related bottlenecks could result in a total breakdown of the system, if it is not completely transformed. One of the key elements involved in transforming the system is improvement of the weather information used to manage the National Airspace System. In 2003, Secretary of Transportation Norman Minetta announced the formation of an interagency Joint Planning and Development Office (JPDO) whose purpose is to facilitate this transformation through the development of an integrated plan for the Next Generation Air Transportation System (NGATS). Information concerning the JPDO is available at *www.jpdo.aero/site_content/index.html.* As a charter member of the JPDO, NASA, through the Aviation Program Element of its Applied Sciences Program, is pioneering new satellite-data applications to better enable NGATS by accurately detecting, characterizing, and forecasting aviation-weather phenomena that affect the airspace system.

In 2002, NASA's Applied Sciences program inaugurated an Advanced Satellite Aviation-weather Products (ASAP) Project at the NASA Langley Research Center (LaRC) in Hampton Virginia. ASAP develops a wide variety of satellite-data applications to improve aviation weather information, which will play an important role in the NGATS. ASAP applications are under development for convective weather, in-flight icing, volcanic ash, aviation turbulence, oceanic winds, ceiling and visibility, and numerical aviation weather modeling, and some of these applications have recently begun to enter the operational pipeline. These and many new applications will rely heavily on new satellite technologies that are scheduled to be launched within the next 5 to 10 years. By bridging the worrisome gap that so often exists between research and operations, ASAP is playing an important role in helping to tangibly justify a national investment in these multi-million-dollar research satellites.

Forecasting Convective Weather and Severe Winter Storms

Convective weather and severe winter storms are the two weather phenomena that have the greatest negative impact on commercial air travel. To help address this problem, ASAP researchers led by **John Mecikalski** [University of Alabama at Huntsville], **Kristopher Bedka** [National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data Information Service (NESDIS)], and **Wayne Feltz** [University

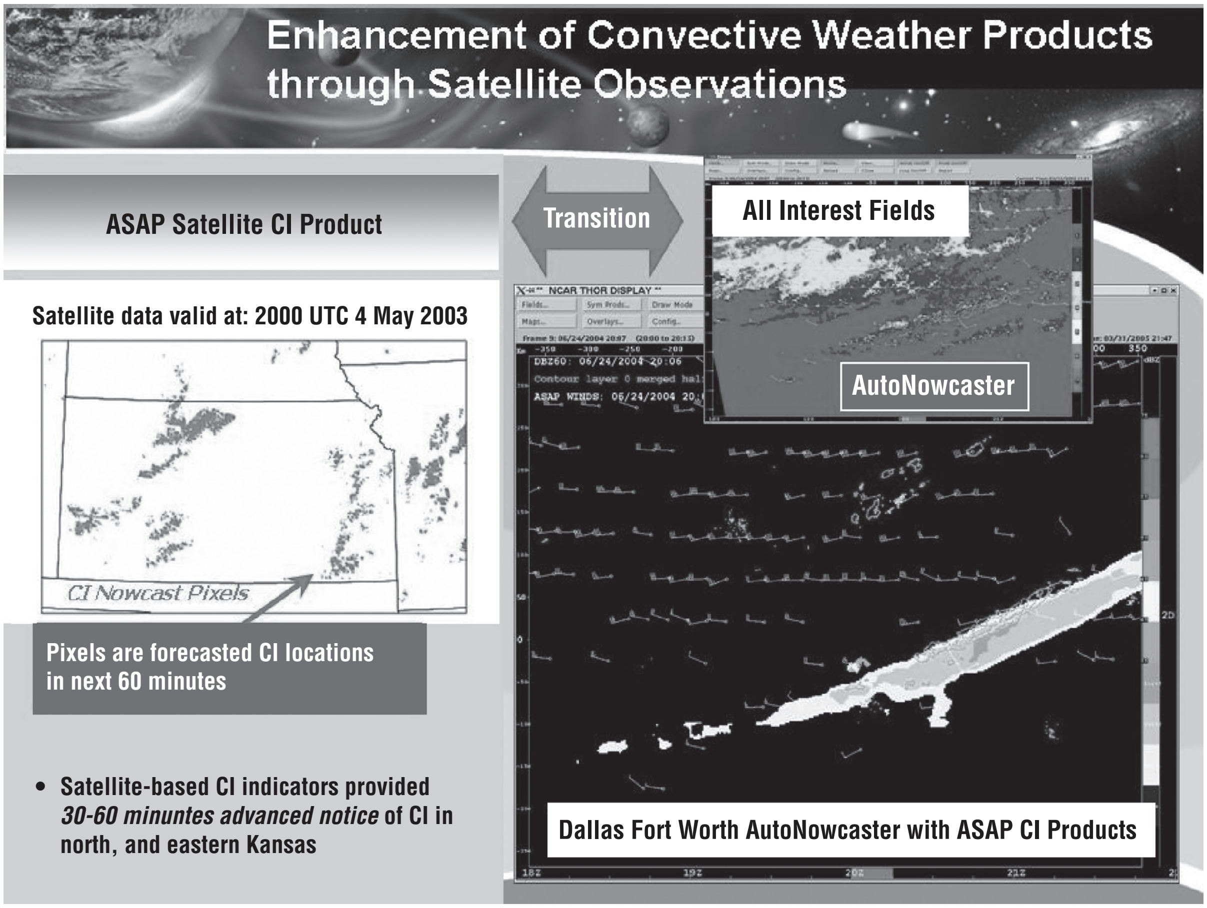
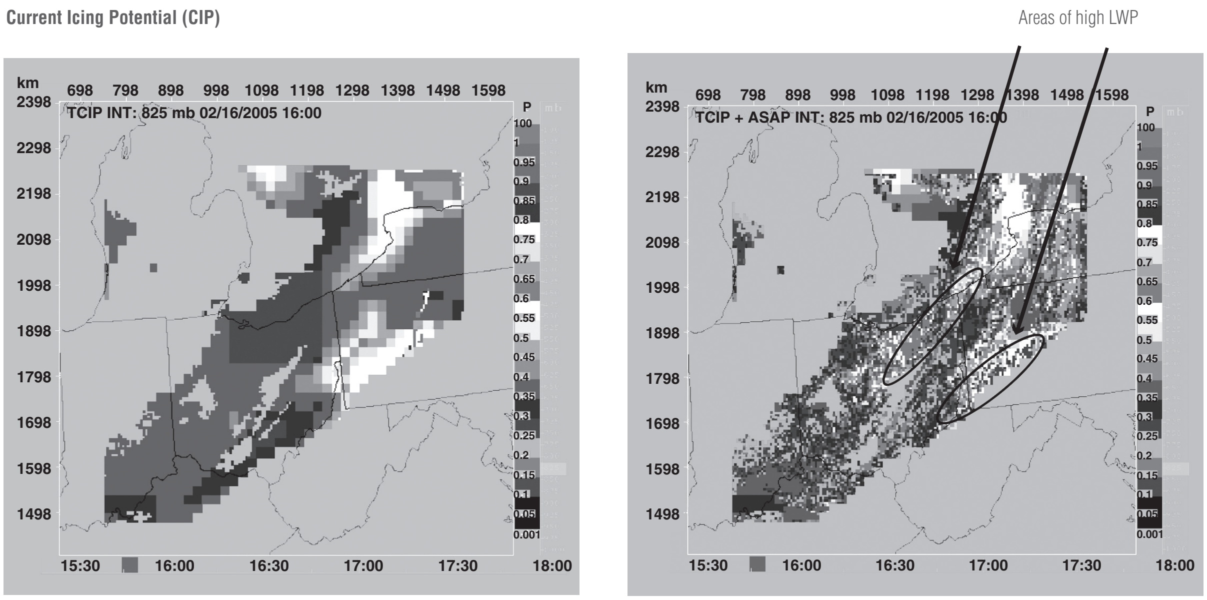


Figure 1. Incorporating ASAP convective initiation fields into operational forecast models results in significant improvements to the accuracy of the severe weather forecasts that are issued. Shown here is an example of the *Autonowcaster* that was installed at Dallas-Fort Worth airport in 2005.

of Wisconsin (UW) Cooperative Institute for Meteorological Satellite Studies (CIMSS)] have developed satellite-data applications that create a radar-echo forecast for severe weather. These applications were described extensively in the January 2006 edition of the *Bulletin of the American Meteorological Society.* Sophisticated cloud-property retrievals, cloud masking, texturing techniques, and channel differencing, are performed on Geostationary Operational Environmental Satellite (GOES) and Moderate-Resolution Spectroradiometer (MODIS) data. These tools identify areas where convective clouds will occur, which correspond to areas with a radar echo greater than 35 DBz—the threshold for strong convective clouds. The data are currently updated every 15 minutes and combined with satellite-derived wind information to create a forecast for radar echoes during the next hour. These satellite-derived convective initiation, development, and advection fields will be incorporated into a variety of weather products being developed for the current National Airspace System. In 2005, the new convective forecasting tools were incorporated into the Federal Aviation Administration (FAA) *Convective Autonowcaster* tool [see **Figure 1**] at the Dallas-Fort Worth and Chicago O'Hare Airports for testing and evaluation. The results of these initial tests were very encouraging and will be outlined in a NASA benchmark report later this year. These applications are expected to significantly improve severe convective-weather warnings called *Convective SIGMETs*, as well as the FAA National Convective Weather Forecast Product graphics currently provided by the NOAA Aviation Digital Data Service (ADDS) and can be viewed at the website, *adds.aviationweather.gov/convection/*. These and similar tools will play an important role for convective-weather management nationwide for the NGATS.

Forecasting Clear Air Turbulence

As air traffic densities increase so will the need to identify the safest and most efficient routes within the National Airspace System. Clear Air Turbulence (CAT) is responsible for most injuries that occur at the altitude at which most commercial aircraft cruise. Using current-generation satellite sounders, ASAP researchers led by **Tony Wimmers** [UW–CIMSS] have developed techniques to identify strong humidity gradients that are often associated with aviation turbulence at and near frontal boundaries. It is expected that the high-vertical-resolution retrievals of temperature and water vapor gradients that will be obtained from the next generation of the National Polar-orbiting Operational



Original estimate at 825 mb. Severity index increases from bottom to top of scale. Areas outside the shaded pixels have negligible icing potential at this level. (Feb 16, 2005)

Modified by inclusion of satellite-derived phase and liquid water path products from GOES, AVHRR, and NASA MODIS. Note: Improved spatial resolution and increased values of severity index corresponding to high liquid water path. (Feb 16, 2005)

Figure 2. Incorporating NASA satellite data into tools used to make icing severity forecasts results in more detailed products that are more useful for predicting possible in-flight icing hazards.

Environmental Satellite System (NPOESS) and GOES sounders will be particularly useful for developing operational applications that take advantage of this capability. The aviation-weather community will begin to reap the benefits of this research when the hyperspectral Cross-track Infrared Sounder (CriS) is deployed by the NASA/NOAA NPOESS Preparatory Project (NPP) satellite in 2009. More significantly, beginning in 2013, the Hyperspectral Environmental Suite (HES), deployed on GOES-R will be able to provide this information continuously over the entire National Airspace System with 5-to-15 minute update capability. The NASA ASAP project has also developed applications to identify CAT associated with the dissipation of gravity waves on the lee side of mountains or downstream from severe-convective weather events. All of these techniques are currently being evaluated or conditioned in collaboration with **Robert Sharman** [National Center for Atmospheric Research (NCAR)] for eventual incorporation into the FAA Global Turbulence Graphic (GTG) within the next few years. Examples of the GTG can be viewed on the NOAA ADDS at *adds.aviationweather.gov/turbulence/*.

Forecasting Icing

The increasing numbers of small commuter aircraft and private pilots, along with the advent of small personal jet aircraft, will present significant new challenges to the safe and efficient operation of the NGATS. In-flight icing hazards can be particularly problematic for these smaller aircraft since they generally take short-to-medium-range routes that place them at lower levels where icing clouds are most prevalent. NCAR has developed a Current Icing Potential (CIP) product that improves upon existing icing products—compare the right and left panels of **Figure 2**—that can help pilots avoid areas of moderate-to-severe icing conditions. The CIP is a powerful tool since it provides a seamless, optimal picture of icing over the entire National Airspace System.

Icing information for the CIP is available from a variety of important sources including, manual and automated pilot reports, radar cloud properties, satellite data, and weather-model output from NOAA's hourly operational Rapid Update Cycle (RUC) model. However, none of these sources alone provides a panacea for forecasting icing. ASAP Project researchers at LaRC have developed methods to retrieve cloud microphysical properties from satellite data to help significantly improve the CIP. Geostationary satellite data are particularly important because they provide a seamless picture over the entire airspace system. The other sources of data used in the CIP such as pilot reports and ground radar are generally scattered around the country or concentrated along heavily used corridors. Ground radar is also limited in coverage and by its horizon. Limitations of satellite data include cirrus overcasts, multilayer difficulties, sun angle, day-night transition, and nighttime limitations of GOES, MODIS, and the Advanced Very High Resolution Radiometer (AVHRR) satellite instruments. After 2012, new data from the GOES-R advanced imagers and sounders, which will have many more spectral channels than the current GOES satellite, as well as 5-minute update capability, will provide even greater fidelity in icing information. NCAR has performed impact studies using ASAP cloud property data that show that these new satellite-data applications can have a significant positive impact on the CIP—see **Figure 2**, right panel.

David Johnson [NCAR] and other researchers are using ASAP cloud properties to help the FAA develop a National Ceiling and Visibility product and **Stan Benjamin** [NOAA Earth System Research Laboratory] is using ASAP data to improve the performance of the RUC model mentioned earlier. **Patrick Minnis** [NASA Langley Research Center— *Science Directorate Staff*] is the lead researcher for NASA ASAP cloud properties. In 2005, the ASAP Project was awarded a grant from the NASA Aeronautics Research Mission Directorate to use the NASA *Project Columbia* super-computer at the NASA Ames Research Center to transition cloud-property data to real-time operations for eventual incorporation into the operational CIP. Research is ongoing at LaRC and NCAR to facilitate this transition. The CIP and ASAP cloud-property graphics, are available to trained forecasters now to improve Terminal Area Forecast (TAF), significant-weather warning (SIGMET) and other forecasts used by airline dispatchers and pilots. Near-real-time ASAP icing-interest fields can be examined at *www-pm.larc.nasa.gov/.* Examples of the current CIP product can be viewed on the NOAA ADDS at *adds.aviationweather.gov/icing/.*

Forecasting Volcanic Ash

Although encounters with volcanic ash and gas clouds are rare, aircraft on transoceanic routes that fly near and downwind of volcanically active regions have experienced engine failures and complete loss of forward visibility due to wind-screen abrasion with nearly catastrophic outcomes. As oceanic and transcontinental air traffic increases, the opportunity for these encounters will increase. To prevent this, the World Meteorological Association and various national weather agencies operate a global network of Volcanic Ash Advisory Center (VAAC) facilities. To safeguard our National Airspace System, the U.S. operates the Washington VAAC at the NESDIS office in Camp Springs, Maryland and the Alaska VAAC at the National Weather Service Alaska Aviation Weather Unit in Anchorage, Alaska. ASAP researchers led by **Michael Pavolonis** [UW CIMSS], have developed and delivered satellite-data applications to NESDIS that use GOES, NOAA, and MODIS data to distinguish between ash and water clouds and to provide automated estimates of volcanic-ash cloud characteristics and height. These tools will be even more capable of resolving volcanic-ash clouds and their altitude with the advent of the next generation of imagers on NPOESS and GOES. ASAP researcher **Earle Williams** [Massachusetts Institute of Technology (MIT) Lincoln Laboratory] is researching the potential for using the global constellation of Department of Defense (DOD) surveillance satellites to provide early warning of volcanic eruptions in real-time.

Conclusion

The success of the Next Generation Air Transportation System will rely heavily on the efforts of the JPDO Weather Integrated Process Team (IPT). The Weather IPT has chartered sub-teams for observations, forecasting, integration, dissemination, training, and policy. Together they are developing a National Aviation Weather Strategy that is a fundamental component of the integrated plan for the NGATS. The NASA Applied Sciences Program fully supports this effort, and is working diligently with the JPDO and its member agencies to develop satellite-data applications that are needed now and which will play an even more important role in the future.

The author serves as the Deputy Program Manager for the Aviation Program Element of NASA's Science Mission Directorate's Applied Sciences Program and as the Project Manager and Principal Investigator of the NASA Advanced Satellite Aviation-weather Products (ASAP) Project at LaRC. He also serves as the co-chair of the JPDO Weather IPT Observations Team.

Editor's Corner

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Lastly, the *Earth Science Reference Handbook: A Guide to NASA's Earth Science Program and Earth Observing Satellite Missions* is now posted as a PDF at *eospso.gsfc.nasa.gov/ftp_docs/1999_Reference_Handbook_Revised.pdf,* and scheduled for printing in late May. The Earth Science Reference Handbook provides a guide to the satellite missions and other elements of NASA's Earth-science program. This volume updates the *1999 EOS Reference Handbook,* now that the first series of Earth Observing System (EOS) missions have been launched and are transmitting data, and broadens the coverage to include not just EOS but also additional NASA Earth-science missions. We welcome comments, corrections, and revisions from the community. Any revisions should be sent to *alan_ward@ssaihq.com,* and will be corrected in the on-line version and incorporated into any future printings of the handbook.

East Greenland Outlet Glaciers: From Ground and Space

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Introduction

Numerous large, fast-flowing outlet glaciers transport mass from the interior of the Greenland ice sheet to the ocean. Changes in the flow configuration of these outlet glaciers modulate ice-sheet mass balance and sea-level. Most sea-level rise predictions, e.g., *Alley et al.,* 2005, consider the near-term contribution from changes in ice sheet-dynamics to be relatively small. These predictions arise from the conventional glaciological theory, e.g., *Whillans,* 1981, that large ice sheets respond slowly (timescales of greater than 10^3 years) to changes in external forcings. Recent reports of large and rapid-flow accelerations on two large Greenland outlet glaciers: Kangerdlugssuaq Glacier and Helheim Glacier challenge this viewpoint. Scientists study these and other similar glaciers as part of the Global Ice Measurements from Space (GLIMS) project.

New field and satellite remote-sensing measurements show that Kangerdlugssuaq Glacier and Helheim Glacier, two fast-flowing tidewater glaciers in South-East Greenland, accelerated 40-300% between 2001 and 2005 and retreated between 3-5 km since July 2003. Together, the catchment basins of these two glaciers encompass approximately 10% of the area of the Greenland ice sheet. The scientists made use of a series of satellite images of the same location and other published reports to reconstruct the last decade or so of flow histories for both glaciers and compared the results with velocities derived from field GPS surveys in summer 2005. The accelerations in flow speeds were accompanied by other changes, including the rapid retreat of calving fronts that had maintained quasi-stable positions for the previous 30 years or so, and a lowering of the ice surfaces by about 100 m, leaving stranded ice on adjacent ridges.

Terminus Positions

Using field survey data, satellite imagery, and aerial photography scientists can reconstruct the *calving front positions* for each glacier. Observations from 1933 are from topographic maps published by the Danish Geodetic Institute. Observations since the 1970s were made using Landsat 3, Landsat 5, Landsat 7, and Terra's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery. The reasearchers primarily focused on imagery acquired during the summer months of June through August—see **Figure 1.**

Kangerdlugssuaq and Helheim glaciers no longer maintain the quasi-stable calving front positions they had occupied for approximately 30 years prior to 2003. Kangerdlugssuaq Glacier had occupied a relatively consistent terminus position from 1972 to 2004, but retreated around 5 km between June 2004 and July 2005—**Figure 1a.** Helheim Glacier retreated around 5 km between August 2003 and August 2005

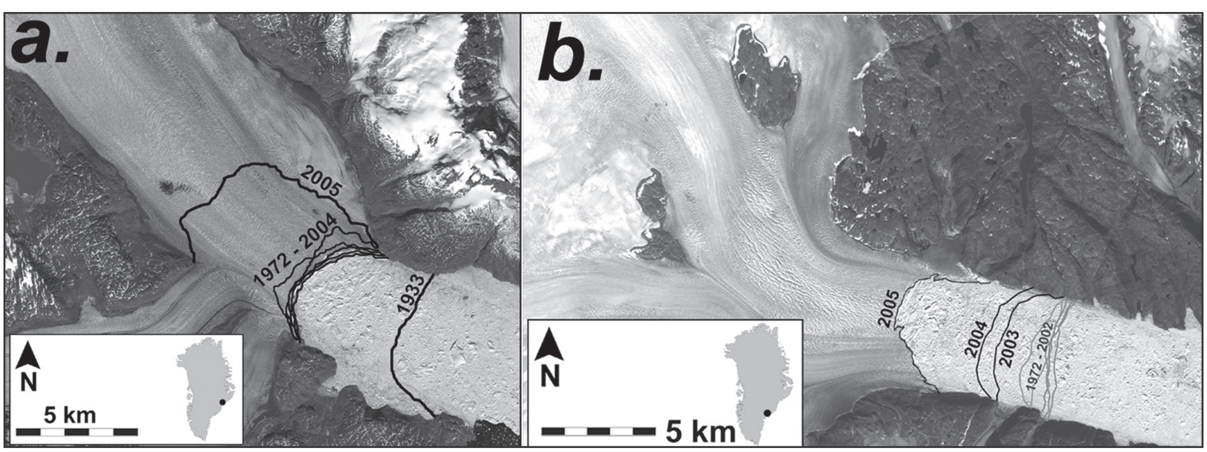

Figure 1: (a) Calving front positions for Kangerdlugssuaq Glacier from aerial photography (1933), Landsat Multispectral Scanner (MSS) (9/7/72), Landsat 4 (8/3/86), Landsat 5 (6/21/92), Landsat Enhanced Thematic Mapper Plus (ETM+) (7/3/01), ASTER (6/30/00, 7/8/02, 6/9/03, 6/25/04) and field surveys (7/21/05). The base image is a portion of a Landsat ETM+ scene acquired July 3, 2001. (b) Calving front positions for Helheim Glacier from aerial photography (1933), Landsat MSS (9/7/72), Landsat 4 (9/11/86), Landsat 5 (8/1/92), Landsat ETM+ (7/8/01) and ASTER (6/20/02, 8/8/03, 7/18/04, 8/29/05). The base image is a portion of an ASTER scene acquired August 8, 2005.

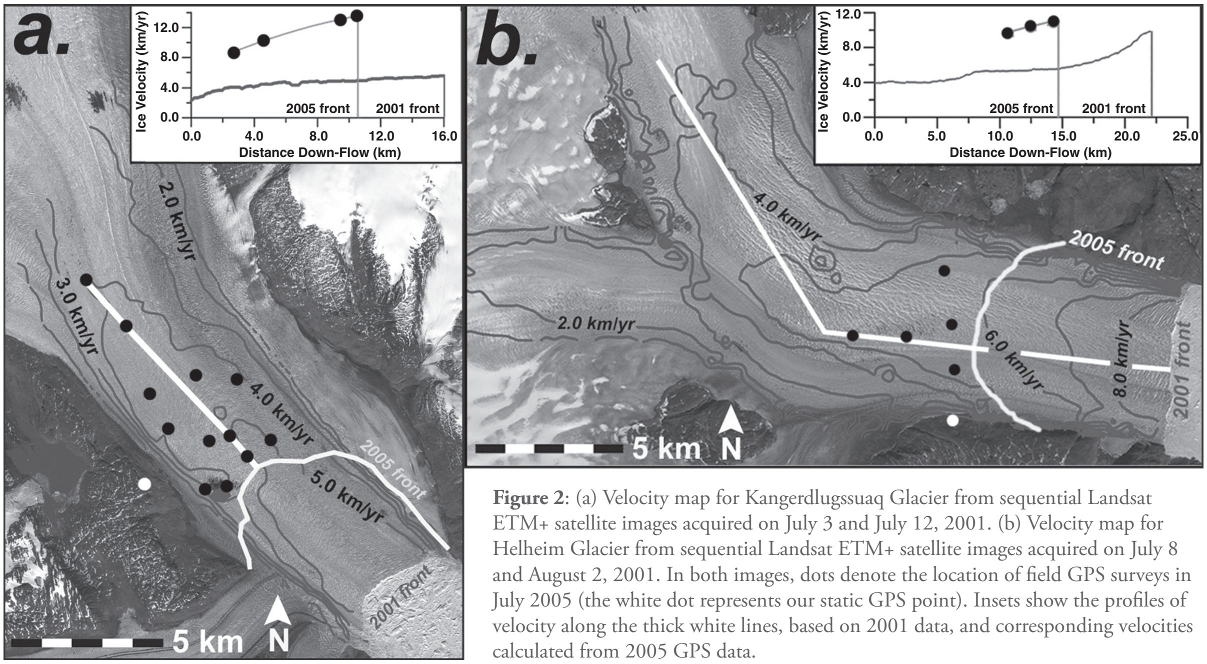

Figure 2: (a) Velocity map for Kangerdlugssuaq Glacier from sequential Landsat ETM+ satellite images acquired on July 3 and July 12, 2001. (b) Velocity map for Helheim Glacier from sequential Landsat ETM+ satellite images acquired on July 8 and August 2, 2001. In both images, dots denote the location of field GPS surveys in July 2005 (the white dot represents our static GPS point). Insets show the profiles of velocity along the thick white lines, based on 2001 data, and corresponding velocities calculated from 2005 GPS data.

after maintaining a near-steady front since 1972—see **Figure 1b.**

Glacier Velocities

By applying a feature tracking technique [*Scambos et al.,* 1992] to sequential high-resolution visible imagery—using either ASTER or Landsat Enhanced Thematic Mapper Plus (ETM+), the researchers could determine flow patterns for 2001 and 2003 for both of the glaciers under study. They matched patterns of brightness in a reference chip from the first image to identical patterns in a search box from the second image and used an automatic cross-correlation technique to help them determine how much the surface features—e.g., crevasses, seracs—had moved from their original position. This method yields a dense array of velocity vectors for each glacier.

The researchers used data from high-precision differential global-positioning system (GPS) surveys in June/July 2005 to determine recent velocities. They surveyed each glacier several times at five to twelve locations along its trunk, over a two-to-five-day time span.

Kangerdlugssuaq and Helheim glaciers have undergone rapid changes in *flow speed*. Speeds on Kangerdlugssuaq Glacier were approximately 5 km/yr in 1988, 1996, and 2001 [*Rignot et al.,* 2004], but accelerated to approximately 6 km/yr in 2003—based on *feature tracking*—and to as much as 14 km/yr in 2005, an almost threefold increase—see **Figure 2a**. Helheim Glacier flowed at around 8 km/yr in 1995 and 2001 [*Rignot et al.*, 2004], around 9 km/yr in 2003, and faster than 11 km/yr in 2005. Scientists observed a 40% increase in flow speed in both the field GPS and ASTER feature-tracking results—see **Figure 2b**.

Surface Lowering

Kangerdlugssuaq and Helheim glaciers exhibited between 100-200 m of *surface lowering* of the main trunks accompanying their rapid retreat and acceleration. Scientists could observe trimlines of stranded ice on the adjacent ridges left behind by thinning glaciers. They could also quantify what they saw with their eyes using ASTER imagery. The ASTER instrument acquires stereo imagery using a nadir (3N) and backward (3B) viewing telescope in the visible near infrared (VNIR) Band 3 [*Yamaguchi et al.,* 1998]. Together, these stereo bands can be used to generate a 15-m horizontal-resolution digital elevation model (DEM) of a 60 km x 60 km scene.

The researchers made a DEM of the glacier surface for four different years—2001, 2002, 2004, and 2005. Both Kangerdlugssuaq and Helheim glaciers underwent approximately 100 m of surface lowering between 2002 and 2005—see **Figure 3.** Thinning rates increased each year, with as much as 50 m of surface lowering occurring between July 2004 and August 2005. In both cases, the thinning extended at least 10 km from the terminus, leading to large volume loss rates.

Discussion

The rapid thinning, acceleration, and retreat of these two relatively nearby glaciers suggests a common triggering mechanism, such as enhanced surface melting due to regional climate warming. The current flow speeds, somewhere between 11–14 km/yr at the terminus, are too fast to be caused solely by internal deformation of the ice. The scientists speculate that warmer summer temperatures observed in this part of Greenland are melting increasing amounts of water that is subsequently stored in surface ponds. This melt water eventually reaches the glacier bed, lubricating the ice-rock interface, leading to acceleration.

Kangerdlugssuaq and Helheim glaciers are not the only glaciers in Greenland known to be undergoing recent rapid changes. Jakobshavn Isbræ, a tidewater glacier at a comparable latitude (69° N) in west Greenland accelerated 30% between 2000 and 2003 [*Joughin et al.,* 2004] and retreated more than 3 km over the same period [*Thomas et al.,* 2003]. The picture emerging from these observations is one in which **large changes in ice dynamics can occur on short timescales** of a few years. If the mechanism triggering the changes of Kangerdlugssuaq, Helheim and Jakobshavn affects other Greenland outlet glaciers, which currently show stable ice dynamics [*Stearns et al.,* 2005], the mass balance of the ice sheet will become increasingly negative, unless balanced by an equal increase in snow accumulation, and rates of sea-level rise will increase much faster than current models predict.

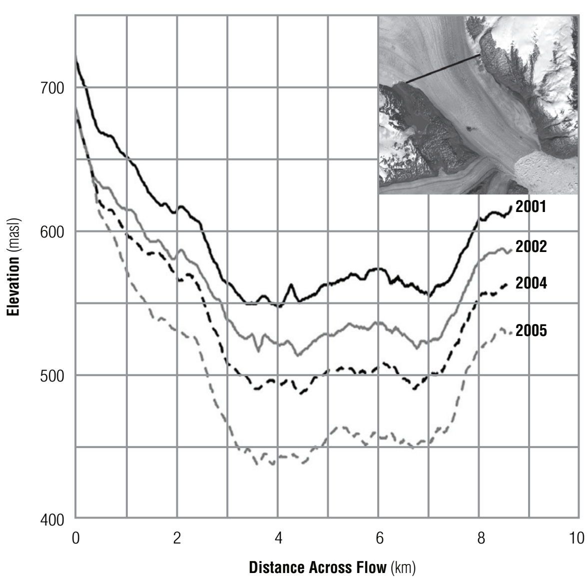

Figure 3: Change in surface elevation on Kangerdlugssuaq Glacier. Elevations are derived from DEMs generated using ASTER stereo images. Uncertainties in each elevation measurement are approximately 15 m.

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28th ASTER Science Team Meeting 2005

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The 28th joint Japan/U.S. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team meeting was held December 12-16, in Palm Springs, CA. About 70 people attended the meeting, including science-team members from Japan and the U.S., and participants from other affiliated organizations.

Following welcoming remarks by **M. Abrams** [NASA/Jet Propulsion Laboratory (JPL)] and **H. Tsu** [Earth Remote Sensing Data Analysis Center (ERSDAC)] presentations were made on the status of NASA and the Earth Observing System (EOS) by **W. Turner** [NASA Headquarters]; on the ASTER instrument by **F. Sakuma** [National Research Laboratory of Metrology]; on the Land Processes Distributed Active Archive Center (LPDAAC) by **B. Bailey** and **K. Duda** [US Geological Survey]; on the Ground Data System (GDS) by **Y. Kannari** [ERSDAC]; and on scene acquisitions by **K. Okada** [ERSDAC].

NASA-EOS information included details of the EOS competition and the shift in emphasis away from refinement of algorithms toward scientific analysis, and on a discussion of the 2006 budget and other unknowns. The LPDAAC report included an update on the status of the on-demand Level 1B (L1B) system upgrade which will optimistically be implemented in April 2006 both in Japan and in the U.S., an update on data pricing and redistribution policy, description of a new processing system, which will make it easier for users to download multiple granules, and an evaluation of four Digital Elevation Model (DEM) production generation systems and the reasons for choosing either *Silcast* software or the software used by GDS.

The ASTER instrument is in remarkably good health even though the Visible Near-Infrared (VNIR) pointing operation is near the design lifetime, as are the Shortwave Infrared (SWIR) and Thermal Infrared (TIR) coolers. There has been a temperature jump in the SWIR detector which is not understood but has stabilized. There has also been a gradual degradation in the radiometric responses of the VNIR and TIR. As of December 5, 2005, 1,080,347 total scenes have been collected, of which 434,600 are daytime scenes with less than 20% cloud cover. Scene collection continues according to a series of criteria including their deemed importance to investigators, and whether good data have already been acquired. Some important acquisitions have not been met due to an enforced reduction in pointings because of the approach of the projected lifetime of the pointing mechanism.

Also in this session **Y. Yamaguchi** [Nagoya University] discussed the status of the global mapping task, the gap-filler task, the nighttime TIR regional-mapping task, and an issue with VNIR pointing. **M. Abrams** [JPL] discussed Landsat data gap issues. **S. Hook** [JPL] discussed ASTER follow on opportunities. **M. Abrams** reported on ASTER related publications including a special issue of *Remote Sensing of the Environment* that featured 17 papers, as well as 10 articles in *IEEE Transactions on Geoscience and Remote Sensing* and a highlight article in *Photogrametric Engineering and Remote Sensing*.

Items which needed to be discussed and decided on in this session include a third round of global mapping which may include areas considered critical by the World Wildlife Federation and may be heavily impacted by Landsat failures; operational scenarios beyond the original ASTER instrument-design lifetime determined by VNIR pointing health, SWIR temperature rise and how to calibrate SWIR in response; and issues related to completing a nighttime TIR map. The failure of the scanning mirror on Landsat 7 has generated a number of ideas to *fill in* for commitments made to provide a decadal and mid-decadal reasonably high resolution map of the globe. One suggestion has been put forth to use ASTER data to fill in the gaps. The ASTER team should assess how it would impact the planned collection of data should this happen.

Working Group Reports – December 16

Operations and Mission Planning Working Group and Science Scheduling Support Group (OMPWG – SSSG)
Chairs: M. Abrams [JPL] and Y. Yamaguchi [Nagoya University]

Among the decisions made by this working group were to continue to submit request packages (STARS) especially for 70–82° N to fill in gaps and to proceed according to the plans presented by **Yamaguchi** for the third round of global mapping. They are waiting for recommendations from Japan Resources Observation System Organization (JAROS) for re-setting the parameters for pointing in the scheduler. Meanwhile the threshold of 100 pointings will be reset as often as needed to avoid pointing shutdown, a mode they have been operating under for the past several months. They are awaiting more input before making a decision on collecting for a nighttime TIR global map.

Radiometric Calibration/ACT Working Group
Chairs: S. Biggar [University of Arizona] and K. Arai [Saga University]

Discussion in this group centered primarily on the SWIR temperature problem, which is manifested as a 1-5 DN change in offset due to a temperature change of 77-to-78.3 K along with a variation in temperature of about

0.4 K peak-to-peak. This is corrected for in the L1B data for normal gain, but not other gain settings. The temperature is expected to rise to 79 K in about April 2006. The offset will probably be fine until about 80 K, which may happen after 2006. This will reduce the dynamic range and may decrease the signal-to-noise at higher temperatures. Several options as to how to deal with the problem were offered, but the group suggests that no action except monitoring be taken at this time (the safest position) and that the instrument team applies the appropriate correction for offset for all gain settings.

Level 1/DEM/Geometry Working Group
Chairs: M. Abrams [JPL] and H. Fujusada [Sensor Information Laboratory Corp]

The group heard an update on Level 1A Data GDS coding because the Level 1A+ tool will be sent to the U.S. in January. The optimistic schedule is for both GDS and the DAAC to be operational in April, at which time all Level 2 products will be on demand. The Distributed Active Archive Center (DAAC) is studying options for the browse product and for a strategy for the Data Pool. The instrument geometry and inter- and intra-telescope registration continue to be excellent. It was pointed out that it is important to consider latitude differences in velocity and base to height for DEM calculations. Mention was made that the DEM software at the DAAC will be replaced soon and the choice will be either *Silcast* or GDS software. The one action item is for the U.S. to develop a procedure to actively notify users of the new Level 1A processing.

Ecology Working Group
Chairs: G. Geller [JPL] and T. Matsunaga [National Institute for Environmental Studies]

Discussion topics for this group included how to pitch in on the Landsat gap-fill issue for a 2006 global cover map. The group feels that they could support it if it doesn't substantially disrupt the existing plan for the third round of the ASTER global map. This would be less likely to be a concern if the limits on ASTER data acquisitions were loosened. The working group members were also asked to provide input on a study by the National Research Council (NRC) at the request of NASA on the measurement needs of the community. On the topic of nighttime TIR, the members felt they wanted to know who would use this data and for what purpose, and they felt the Temperature/Emissivity Working Group would provide that information. This working group had many presentations by members of the group and other team members on ecology topics.

Geology Working Group
Chairs: D. Pieri [JPL] and M. Urai [GSJ, AIST]

This group had four open action items to consider. They decided to generate a set of questions to assess how Landsat gap-filling will impact ASTER geology investigations. The group wrestled with questions such as:

- what will be the typical size of a gap request;
- what parts of the world are more likely to be requested;
- how frequently will a given request be made.

They expressed a need for the ASTER Global Volcano STAR to be continually revisited and all Geology STARS be re-evaluated because of pointing and scheduling resource limitations, and decided on a goal of at least one cloud-free baseline image of every STAR volcano. The group still needs to gather final Global Mapping 3 inputs. Inputs are due to the chairs by the first of January. There was considerable discussion of the nighttime TIR mapping issue and discussion of the strengths of such a map, and an example of a case useful to the GLIMS group by **J. Kargel** strengthening the cause. This group had many presentations on scientific results of various volcanology studies.

Temperature/Emissivity Working Group
Chairs: A. Gillespie [University of Washington] and H. Tonooka [Ibaraki University]

The group had three agenda items to cover: (1) changes to the TES software; (2) prioritization of TIR acquisitions; and (3) responding to a request for the project to justify continuing nighttime TIR acquisitions. With regard to software changes, the threshold test based on min-max spectral contrast will be disabled. This change should improve the overall appearance of images and reduce the number of strongly inaccurate products, however, users should be aware that it may lead to loss of accuracy for scenes obtained over some low-contrast surfaces in most of the standard data products. The iterative correlation for reflected downwelling sky irradiance will also be disabled.

With regard to prioritizing ASTER acquisitions and justifying continued nighttime TIR acquisitions, the two areas seem to go together. The TES group felt that the strongest justification they could give for continuing to obtain nighttime TIR data was because these nighttime scenes have the advantage of not having the effects and confusion of topographic effects and solar heating, and this makes them ideally suited to meeting a number of ASTER's formal observation priorities. For example, the ASTER instrument is uniquely equipped to acquire the imagery needed to produce a *global emissivity map*, and the completion of such a map remains a formal priority for ASTER. ASTER also prioritizes studying volcanoes and other heat islands, which are best observed using nighttime TIR acquisitions. More recently, the team decided to prioritize the study of geothermal anomalies, also best accomplished using nighttime TIR data. In addition, ASTER is used for *thermal inertia mapping,* a standard well-understood technique routinely used in planetary studies, and one that requires nighttime data.

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Atmospheric Infrared Sounder Science Team Meeting

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The Atmospheric Infrared Sounder (AIRS) Science Team Meeting was held at the Beckman Auditorium at Caltech in Pasadena March 7-10, 2006. The meeting had the greatest turnout of any AIRS Science Team meeting with over 90 participants, and 51 presentations. All talks are available on the AIRS Project website at *airs.jpl.nasa.gov.*

The meeting opened with **Moustafa "Mous" Chahine** [NASA/Jet Propulsion Laboratory (JPL)—*AIRS Team Leader*] giving a welcome and emphasizing the importance of publications to the team. In 2005, the AIRS science community published over 100 papers in journals and conference reports. **Tom Pagano** [JPL—*AIRS Project Manager*] spoke next, and gave a project overview and indicated all is well with the AIRS and AMSU instruments. **Charles Elachi** [JPL—*Center Director*] made a surprise visit to the meeting and expressed his pleasure with the progress made by the AIRS team and the importance of this work to the laboratory. The introduction concluded with a Headquarters perspective given by **Bruce Doddridge** [NASA HQ—*Program Manager for the Tropospheric Chemistry Program*]. Doddridge indicated that despite the inevitable cuts to science funding, HQ will make every attempt to preserve the AIRS Science Team intact.

AIRS Data for Validating Climate Models

An exciting development on the AIRS Project is the increased use of AIRS data by climate modelers. **Andrew Gettleman** [University Corporation For Atmospheric Research (UCAR)] presented on the use of AIRS water-vapor data to provide insight into climate forcing. He showed how the greenhouse effect is correlated with sea surface temperature, and that water-vapor feedback is positive. In a similar presentation, **Tim Barnett** [Scripps Institute] showed how the current climate models show more than 50% error in the water-vapor amounts, with the greatest errors at mid-latitudes and mid-altitudes. **David Neelin** [University of California Los Angeles (UCLA)] presented his work on the tropical moist dynamical theory from AIRS and the Tropical Rainfall Measuring Mission [TRMM]. **Joan Alexander** [NorthWest Research Associates (NWRA)] showed that the AIRS "sees" numerous cases of gravity waves in the radiances. Gravity waves affect stratospheric dehydration, polar-ozone loss, and the timing of summer easterlies. AIRS observations can be used to constrain the parameterization of general-circulation models (GCMs).

Baijun Tian [JPL] presented his work where he used AIRS data to examine the vertical moist thermodynamic structure and spatial-temporal evolution of the Boreal Winter Tropical Intraseasonal Oscillations (TISO) or the Madden Julian Oscillation (MJO) [*Tian*, 2005]. The AIRS data show that the oscillation is a result of an elegant interplay between rainy and clear conditions over the tropical Indian and western Pacific Oceans. The MJO convection is preceded by a low-level warm and moist anomaly and followed by a low-level cold and dry anomaly. However, this relationship is not well captured by the reanalysis data because of the lack of radiosonde observations in the tropical Indian Ocean.

In a similar presentation, **Xiouhua (Josh) Fu** [University of Hawaii] presented his work showing the weather patterns that lead up to the Boreal Summer TISO (BSISO) using AIRS data [*Fu*, 2006]. The AIRS data show much larger perturbations in the moisture in the troposphere than seen in models. AIRS data also show a drying of the boundary layer below the BSISO convection most likely due to downdrafts. An increase in sea surface temperature and a moistening of the boundary layer are observed prior to the BSISO convection that could lead to a feedback effect destabilizing the atmosphere.

Andrew Dessler [Texas A&M] showed the simple trajectory model with a fixed relative humidity (RH) limit does a good job of reproducing AIRS annual average water vapor. **Dan Feldman** [California Institute of Technology (Caltech)] showed that AIRS has moderate descriptive power for the temperature profile of the Tropical Tropopause Layer (TTL). The TTL is the region that affects troposphere-stratosphere radiative exchange. **George Aumann** [JPL] showed that the tops of Deep Convective Clouds (DCC) are covered with thick cirrus. The distribution of the DCC may be related to trends in the frequency of severe weather. **Eric Fetzer** [JPL] summarized the validation effort for *Version 4.0 (v4)*, which forms the basis of more than 20 peer-reviewed validation papers expected to appear in the May 2006 issue of *Geophysical Research Letters.* **Brian Kahn** [JPL] concluded the science discussions with his work using AIRS data to measure the amount and altitude of thin cirrus clouds. Kahn used ARM data in the Western Pacific to show the accuracy of AIRS cloud-top temperatures and that they agree well with the Moderate Resolution Spectroradiometer (MODIS) determinations.

AIRS Atmospheric Constituents Product Generation and Validation

The next session in the meeting addressed AIRS Atmospheric Constituent Research Products, their generation and validation. **Laura Pan** [National Center for Atmospheric Research (NCAR)] opened this session and presented her validation efforts on the AIRS Ozone Profiles. Her findings showed AIRS has good vertical resolution near the tropopause and match aircraft observations very well. The AIRS water vapor and ozone (O_3) form a pair of tracers for diagnostic mixing.

The next four talks described techniques to use AIRS to measure carbon dioxide (CO_2):

- **Richard Engelen** [European Centre for Medium-Range Weather Forecasts (ECMWF)] who used 4D-Var data assimilation to arrive at estimates of atmospheric CO_2 concentrations. The effect of assimilating AIRS data was to increase CO_2 concentrations in the model in the upper troposphere and reduce CO_2 concentrations in the model in the Southern Hemisphere stratosphere.

- **Cyril Crevoisier** [Princeton] presented his work using Nonlinear Regression and Neural Networks to retrieve CO_2 concentrations and showed good results.

- **Mous Chahine** [JPL] showed his direct retrieval of CO_2 using the method of Vanishing Partial Derivatives. His work shows good agreement with Matsueda data. Chahine also presented his first global maps of mid-tropospheric CO_2 concentrations for the months of January, May and October 2003. Chahine indicates that knowledge of the mid-tropospheric CO_2 is necessary to provide the background levels for the models for future observations of the sources and sinks in the boundary layer.

- **Chris Barnet** [National Oceanic and Atmospheric Administration (NOAA)] indicated that the Washington Volcanic Ash Advisory Center is now receiving the rebroadcast AIRS sulfur dioxide (SO_2) flag. Barnet also showed favorable validation results for his retrieved methane (CH_4) product, showed his progress in retrieval of CO_2, and showed correlations of carbon monoxide (CO) and CO_2 in biomass burning zones.

Wallace McMillan [University of Maryland Baltimore County (UMBC)] showed the validation results of AIRS CO using Intercontinental Chemical Transport Experiment, North America [INTEX-A] results. McMillan says AIRS CO has an accuracy of better than 15% in the mid-troposphere. He also showed the good correlation of AIRS CO daily maps and the NASA Goddard kinematic trajectory model.

Larrabee Strow [UMBC] showed validation results for his retrievals of nitric acid (HNO_3), SO_2, CH_4, CO_2 and dust. Strow's message is that these constituents affect the atmospheric temperature and water vapor retrievals, and are limiting their accuracy until accounted for.

AIRS Data Assimilation for Weather Forecast Improvement

James Cameron [United Kingdom Meteorological Office (UK Met Office)] presented work on assimilating AIRS data. **John LeMarshall** [NOAA Joint Center for Satellite Data Assimilation (JCSDA)] showed a 6-hour improvement in the 5-day forecast when assimilating AIRS data. When all the AIRS footprints are assimilated, rather than only 1 in 18, even better results are obtained. LeMarshall is examining the benefits of assimilating more channels. **Brad Zavodsky** [Short Term Prediction Research and Transition Center (SPoRT)] showed the improvement in the 48-hr forecast when assimilating AIRS Level 2 (L2) data. **Keith Brewster** [University of Oklahoma] also showed a positive impact in the 6-hr and 12-hr forecast when assimilating AIRS L2 data. The need for real-time L2 data from AIRS has prompted the AIRS Project to work with GSFC to generate such a product and expect to have one online this year. **Joanna Joiner** [Goddard Space Flight Center (GSFC)] analyzed the effects of channel selection on AIRS assimilation and **Eugenia Kalnay** [University of Maryland (UMD)] presented the application of the Local Ensemble Transform Kalman filter to AIRS data assimilation.

The remainder of the presentations focused on development of the AIRS Standard Products. **Steve Friedman** [JPL] led the discussions and presented the schedule for *Version 5.0 (v5)*, now to be delivered to the GSFC Distributed Active Archive Center (DAAC) in August of 2006. The development is structured into 5 teams. **Wallace McMillan** [UMBC], team leader for the minor constituents group said CO and CH_4 products will be ready for *v5*. The O_3 product will be no worse than *v4,* and *v5* will also have an SO_2 flag and a Dust Score. **Bill Irion** [JPL] showed the effects of modified damping parameters on AIRS ozone retrievals.

Larrabee Strow [UMBC—*Radiative Transfer Algorithm Team Leader*] showed improvements in the *v5* RTA due to changes in the transmittances based on radiosondes and the addition of Non-LTE emission correction. **Phil Rosencranz** [Massachusetts Institute of Technology (MIT)] discussed using AIRS clear ocean data to evaluate the AMSU bias.

Chris Barnet [NOAA—*Emissivity Team Leader*] said the emissivity regression retrieval is installed in *v5*, and yet the limitations on emissivity retrieval are in the cloud clearing. **Evan Fishbein** [JPL] showed that using channels which are not sensitive to surface skin temperature in cloud clearing greatly improve the emissivity retrieval over land. **Bob Knuteson** [University of Wisconsin (UW)] used the ARM Southern Great Plains site to validate AIRS temperature and emissivity.

Sung-Yung Lee [JPL—*AIRS-Only Retrieval Team Leader*] showed the current version of the AIRS-Only retrieval works well but has more outliers. **Xavier Calbet** [European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)] and **Bill Blackwell** [MIT Lincoln Laboratory (MIT/LL)] also gave presentations on IR-Only retrievals.

John Blaisdell [GSFC] presented for **Joel Suskind** [GSFC—*Error Estimation Team Leader*] a new empirically trained error predictor. The method shows considerable skill, but more work is needed. Blaisdell also presented comparison for the accuracy of AIRS *v5* and *v4* clear column radiances and retrievals. **Larrabee Strow** [UMBC] compared AIRS cloud-cleared radiances to ECMWF.

Friday's session focused on calibration and data processing. **Hank Revercomb** [UW] presented validation of AIRS radiances using Scanning High-resolution Interferometer Sounder (HIS), and **George Aumann** [JPL] showed validation using SST. The consensus is that AIRS data are accurate to about the 0.2 K level for most channels. **Steve Broberg** [JPL] showed radiance comparisons of AIRS with MODIS and HIRS using tropical ocean and Antarctic scenes. **Denis Elliot** [JPL] gave a progress report on the effort to produce spatial response functions in-flight for the AIRS footprints. **Greg Leptoukh** [GSFC] showed how the *Giovanni* tool allows quick exploration and online analysis of remote sensing and model data. Presentations ended with **Vicky Meyers** [JPL] giving a demonstration of the new *Harvest* tool for submitting changes to the AIRS processing system.

The AIRS Science Team Meeting was a milestone in the lifecycle of AIRS. In the past, the group's primary focus was on product generation and validation, but now the focus is more on science investigations and operations. Product development continues, however, with improvements to retrievals over land and polar regions and with new research products for surface emissivity and atmospheric composition. The team is functioning well with members sharing their various techniques for deriving and improving product accuracies and comparing scientific results. All things considered, the AIRS Science Team Meeting was an unqualified success.

Tian, B., D. E. Waliser, E. Fetzer, B. Lambrigtsen, Y. Yung, and B. Wang. 2005. Vertical Moist Thermodynamic Structure and Spatial-temporal Evolution of the Madden-Julian Oscillation in Atmospheric Infrared Sounder Observations. *J. Atmos. Sci.*, In Print.

Xiouhua Fu, Bin Wang, Li Tao. 2006. Satellite data reveal the 3-D moisture structure of Tropical Intraseasonal Oscillation and its coupling with underlying ocean. *Geophys Res. Lett.* **33**, L03705, (doi:10.1029/2005GL025074).

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The group therefore strongly recommends continuing nighttime acquisitions. They also suggest changing the scheduler to allocate bits instead of scenes, which has severely limited data acquisition in the past, but apparently this change is not easy to make. They also recommend replacing the current project high/medium/low priority map with a land cover map, and that areas where scenes have already been obtained and snow-covered areas be excluded.

STAR Committee

The STAR committee approved three new STARS. Old STARS will expire in 2006 including the GLIMS STAR which has about 2500 glacier targets and the volcano STAR which also has a large number of targets.

After the working group meetings **Y. Yamaguchi** presented a summary of the teams decisions. **M. Kato** announced that the next meeting will be held in Japan, probably Tokyo, in June. **H. Tsu** and **M. Abrams** had a few final words and closed the final plenary session.

Workshop on Exploring and Using MISR Data

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A one-day workshop on *Exploring and Using Multi-angle Imaging SpectroRadiometer (MISR) Data*, organized by the Atmospheric Science Data Center [ASDC] at NASA Langley Research Center, was held in Sydney, Australia March 20 in conjunction with the Fourth International Workshop on Multi-angle Models and Measurements (IWMMM-4). The 29 attendees heard presentations about the MISR instrument and research results from the various data products from **David J. Diner** [NASA/Jet Propulsion Laboratory (JPL)—*MISR Principal Investigator (PI)*]. **Nancy Ritchey** and **Linda Hunt** [both from Science Applications International Corporation (SAIC)—*ASDC User and Data Services*] spoke about MISR data access and tools, and **Brian Rheingans** [JPL] presented MISR data organization, geolocation, and data analysis. **John Martonchik**, [JPL—*MISR Science Team member*], and **Charles Thompson** [JPL—*misr_view developer*] were also on hand to assist participants and answer questions. Positive feedback was received from all participants regarding the workshop presentations, content, and hands-on exercises.

MISR measurements are designed to improve our understanding of the Earth's environment and climate. Viewing the sunlit Earth simultaneously at nine widely spaced angles, MISR provides ongoing global coverage with high spatial detail, and its imagery is carefully calibrated to provide accurate measures of the brightness, contrast, and color of reflected sunlight. MISR provides new types of information for scientists studying Earth's climate, such as the partitioning of energy and carbon between the land surface and the atmosphere, and the regional and global impacts of different types of atmospheric particles and clouds on climate. The change in reflection at different view angles affords the means to distinguish different types of atmospheric particles (aerosols), cloud forms, and land-surface covers. Combined with stereoscopic techniques, this enables construction of 3-D models and estimation of the total amount of sunlight reflected by Earth's diverse environments.

JPL built the MISR instrument for NASA. MISR was launched into sun-synchronous polar orbit aboard *Terra*, NASA's first Earth Observing System (EOS) spacecraft, on December 18, 1999, and has continuously provided data since February 24, 2000. The data are publicly available from the NASA Langley Research Center ASDC.

The Workshop was intended for both new and experienced MISR data users. Participants from a diverse set of international institutions learned about the scientific applications, calibration, geometry, and analyses of the MISR measurements. The Workshop focused on the available data products and tools—both MISR and Geographic Information System (GIS)—to view and analyze the data, as well as how to obtain the products.

David J. Diner [JPL—*MISR PI*] presented an overview of the mission and capabilities, and highlighted some recent explorations of MISR data for Earth-science research. Examples included unique results from the December 26, 2004, Indian Ocean tsunami; an immense wintertime pool of pollution over Bihar, India; mapping Greenland ice sheet surface roughness; surface dewatering resulting from the January 26, 2001, earthquake in Gujarat, India; relationship between surface vegetation bidirectional reflectance and canopy structure; and retrieving aerosol optical depth globally over all surface types. Diner then presented MISR observational principles and an overview of the data products.

Nancy A. Ritchey [SAIC—*NASA ASDC*] gave a presentation on MISR terminology, how to obtain MISR data products and information, and on using the On-Line Visualization Tools. The MISR Order and Customization Tool made its debut at the Workshop. This tool, developed at ASDC in collaboration with JPL, enables users to order and customize data in a single interface. Some features of the new tool are multiple consecutive and non-consecutive path and orbit searches, and sorting search results by date, path, orbit, camera, and file version. Customization options include subsetting by parameter, block, and spatial coordinates; additional latitude and longitude layers; unpacking and unscaling applicable fields; and output data in HDF-EOS-stacked block grid or conventional grid formats.

Linda A. Hunt [SAIC—*NASA ASDC*] demonstrated how some of the available tools could be used to explore the MISR data products. With Sydney, Australia as the hypothetical site of interest, the web-based *Lat/Lon to MISR path block tool*, the *Browse Image Viewer,* and the *MISR Orbit/Date Conversion Tool* were used to determine the MISR files of interest. The *misr_view tool* and MISR/ENVI tool were used to visualize parameters from several data products in the Sydney area. Other utilities for reading and converting data were discussed, and the soon-to-be-released MISR Level 3 analysis tool was previewed.

Brian Rheingans [JPL] presented MISR Data Analysis and Tools. The projection used for the MISR data products, Space Oblique Mercator (SOM), was explained as well as the differences between the data output formats—stacked block vs. conventional grid—available through the MISR Order Tool. Rheingans also presented the new MISR Toolkit that provides simplified MISR data access and geolocation functionality via a set of software routines callable from either C or IDL programs. During the remainder of the Workshop, an interactive hands-on session was conducted. The participants learned how to use *misr_view* to open, view data values, and visualize data as true-color, false-color using multi-angle composite and stereo anaglyphs. With the assistance of MISR Team members and ASDC User and Data Services staff, participants also explored the MISR data.

For more information about all ASDC data holdings, MISR data products, or this MISR Workshop, please visit: *eosweb.larc.nasa.gov.*

Announcement: Hardbound Version of Special Issue of *Solar Physics* Dedicated to SORCE Released

The Earth Observer is pleased to announce the release of a hardbound version of *Solar Physics* [(2005) 230:1-2] entitled *The Solar Radiation and Climate Experiment (SORCE): Mission Description and Early Results.* **Gary Rottman, Tom Woods,** and **Vanessa George** from the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder, all served as guest editors for this hardbound reprint, which includes contributions from many different authors. All 18 of the SORCE papers are available on the Springer Publishing Company's website: *www.springer.com.*

The SORCE mission is an element of NASA's Earth Observing System with four instruments to measure the solar radiation incident at the top of Earth's atmosphere—including total solar irradiance (TSI) and solar spectral irradiance (SSI). The Principal Investigator (PI) is **Tom Woods** [LASP], who succeeded **Gary Rottman** [LASP] when he retired in 2005. NASA's Goddard Space Flight Center's **Bob Cahalan** is Project Scientist, **Douglas Rabin** is Deputy Project Scientist, and **Bill Ochs** was Project Manager. **Don Anderson** [NASA Headquarters] is Program Manager.

LASP developed, calibrated, and tested the instruments on SORCE before integrating them on a spacecraft procured from Orbital Sciences Corporation. SORCE launched in January 2003, and the first validated science data were delivered approximately two months after launch. Science and mission operations are conducted from LASP's Mission Operations Center. Results from SORCE are improving our understanding and generating new inquiry regarding how and why solar variability occurs and how it impacts Earth's energy balance, atmosphere, and long-term climate changes.

This special issue of *Solar Physics* provides thorough documentation of the SORCE mission to date, and will be useful as a reference document for years to come.

NCAR Workshop on Air Quality Remote Sensing From Space: Defining an Optimum Observing Strategy

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A workshop was held at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, February 21-23, 2006, titled *Air Quality Remote Sensing From Space: Defining an Optimum Observing Strategy (AQRS).* The organizing committee of this meeting comprised representatives from the different constituencies interested in Air Quality (AQ) remote sensing and included **David Edwards** [NCAR], **Philip DeCola** [NASA Headquarters (HQ)], **Jack Fishman** [NASA Langley Research Center (LaRC)], **Daniel Jacob** [Harvard University], **Pawan Bhartia** [NASA Goddard Space Flight Center (GSFC)], **David Diner** [NASA/Jet Propulsion Laboratory (JPL)], **John Burrows** [University of Bremen], and **Mitch Goldberg** [NOAA/ National Environmental Satellite Data and Information Service (NESDIS)]. The primary goal of this community meeting was an examination of the key measurement characteristics that are required for the successful use of satellite remote sensing in measuring environmentally significant pollutant trace gases and aerosols. It engaged over 150 scientists and AQ stakeholders from North America and Europe.

The Workshop sessions were arranged around the following specific objectives:

1. provide an overview of current and future operational requirements for AQ satellite observations;
2. review the current space-based capabilities for measuring tropospheric trace gases and aerosols and assess the benefits and limitations for AQ applications;
3. further the development of techniques for combining space-based measurements with models, particularly at the regional scale, for estimating sources and sinks, and separating the contributions of local production and transported pollution;
4. examine the horizontal, vertical, and temporal measurement resolutions required to capture the variation of the important atmospheric constituents and processes determining AQ; and
5. explore future mission concepts and detail the parameters of an optimum observation system for AQ studies from space.

The National Research Council is currently conducting a *Decadal Survey* to determine the priorities for the next round of space missions for *Earth Science and Applications from Space.* The Workshop provided an opportunity to develop a community consensus as to the priorities for future space-based AQ observations. A statement has been submitted to the *Decadal Survey* and the conclusions of this exercise are summarized below.

AQ measurements are urgently needed to understand the complex consequences of increasing human-produced emissions, the biogenic response to changing temperature and humidity, and the escalating incidence of fire. The Workshop identified four principal areas in which satellite observations are crucial for future AQ basic research and operational needs: (1) AQ characterization for retrospective assessments and forecasting to support air-program management and public-health advisories; (2) quantification of emissions of ozone and aerosol precursors; (3) long-range transport of pollutants extending from regional-to-global scales; and (4) large puff releases from environmental disasters. The recent advances in tropospheric remote sensing from low-Earth orbit (LEO) instruments such as Measurements of Pollution in The Troposphere (MOPITT), Global Ozone Monitoring Experiment (GOME), Moderate Resolution Imaging Spectroradiometer (MODIS), Multi-angle Imaging SpectroRadiometer (MISR), Scanning, Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY), Ozone Monitoring Instrument (OMI), and Tropospheric Emission Spectrometer (TES) have demonstrated the value of using satellites for both scientific studies and environmental applications. The Workshop agreed that the measurement capabilities for tropospheric ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), formaldehyde (HCHO), sulfur dioxide (SO_2), and aerosols need to continue and, at the same time, instrument capabilities and measurement algorithms for these species need to improve.

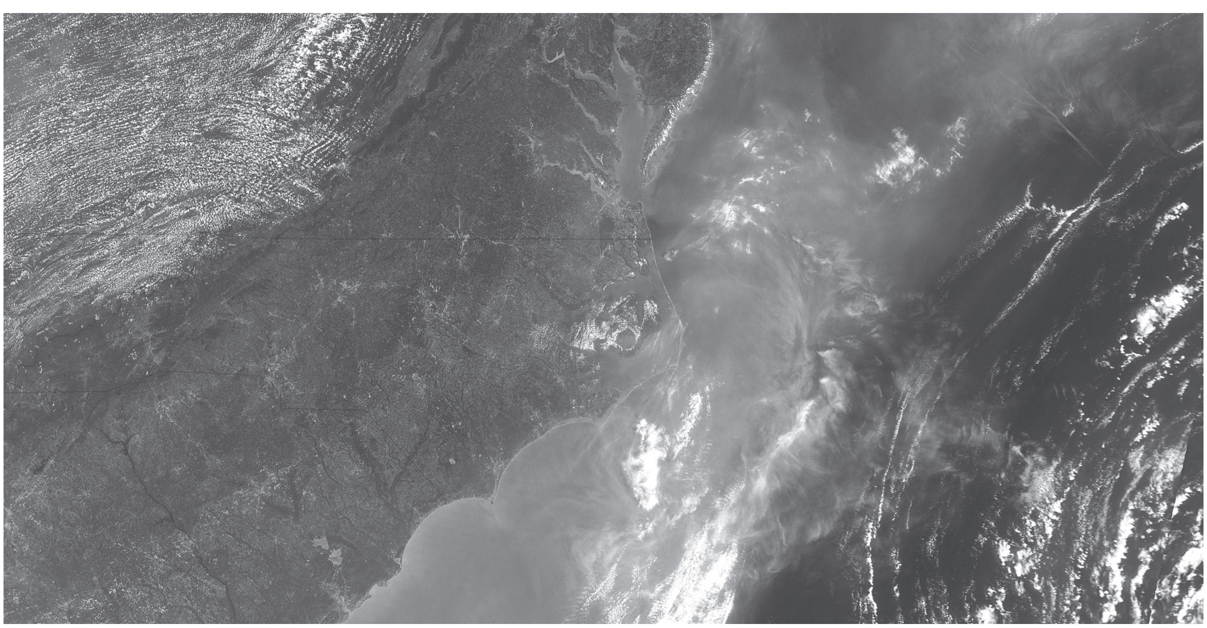
Ideally, the AQ community envisions a scientific and observing framework for atmospheric composition that is analogous to that achieved for weather forecasting. In particular, our national weather prediction system relies on the combination of observations from geostationary Earth orbit (GEO), LEO, and suborbital and surface platforms to derive a 4-dimensional view (3 spatial dimensions plus temporal) of the physical state of the atmosphere. Similar capability for AQ constituents will be required for AQ characterization and *chemical weather* forecasting.

Workshop participants reached a consensus that multispectral sentinel missions—GEO or Lagrangian (L-1) orbit—that have high spatial and temporal resolution, and are able to provide some species concentrations within the boundary layer, would be most beneficial to the AQ community. At the present time, GEO meets this measurement capability with the least amount of risk, and the greatest societal benefit (from a U.S. perspective) would be derived from placing such a satellite in an orbit capable of observing North America. The NOAA GOES-R operational suite of measurements from GEO will have capabilities for monitoring O_3, CO, and aerosol that are relevant to AQ. However, since NOAA's primary objective is improving weather forecasting, observations are not currently optimized for AQ applications and critical multi-spectral measurements in the ultraviolet (UV) and near-infrared (IR) are not planned. Thus the Workshop stated the need for a new generation of dedicated AQ satellite missions that will also be part of an integrated observing system including air-monitoring networks, *in situ* research campaigns, and 3-D chemical-transport models. The Workshop emphasized the need for continued collaboration with NOAA to determine the most efficient and synergistic use of resources to meet AQ observational objectives from both GEO and LEO. This is particularly important since operational global measurements of tropospheric gases and aerosols from National Polar-orbiting Operational Environmental Satellite System (NPOESS) and other NOAA and European satellite systems will be needed to complement GEO AQ observations.

Over the longer term, global measurements for AQ with a sentinel capability could be obtained from L-1 orbit, but this approach requires more technical development to ensure the essential multi-spectral measurements and mitigate risk. Other approaches for AQ measurements discussed at the Workshop included multiple satellites flying in LEO formation and satellites perched in mid-Earth orbit (MEO), which can provide time-resolved observations—about 5 per day at mid-latitudes covering all longitudes—but with UV and visible measurements switching monthly between north and south. Each of these approaches has value and may provide synergy with objectives put forth by other Earth-system-science disciplines. The LEO-formation and multiple MEO instruments with limb-viewing capability provide better vertical resolution in the middle and upper troposphere needed for understanding the impact of tropospheric and stratospheric chemistry on climate, and the resolution in the stratosphere needed to monitor the stability of the atmospheric ozone layer. The Workshop also concurred that a LEO would be the best platform for gaining an understanding of the composition and size characteristics of atmospheric aerosols by means of multi-angle, spectropolarimetric, and stereoscopic-imaging techniques in conjunction with active—high-spectral-resolution lidar—measurements, which could provide aerosol information throughout the troposphere.

Further information about the Workshop, and the proceedings and presentations are available at *www.acd.ucar.edu/Events/Meetings/Air_Quality_Remote_Sensing/index.shtml.*

Hazy air from along the eastern seaboard from Pennsylvania to Georgia was lingering over coastal regions and spreading out over the Atlantic Ocean on July 26, 2005. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra spacecraft observed this image as it passed over the area. Although many meteorological and human factors influence air quality, among the major culprits are high atmospheric pressure systems. High pressure usually creates a stable—stagnant—region of air in which the emissions from our vehicles, power plants, and fires keep piling up. Image courtesy of the MODIS Rapid Response Team, NASA GSFC.



NASA Disassembles and Reassembles Tropical Storm Gert

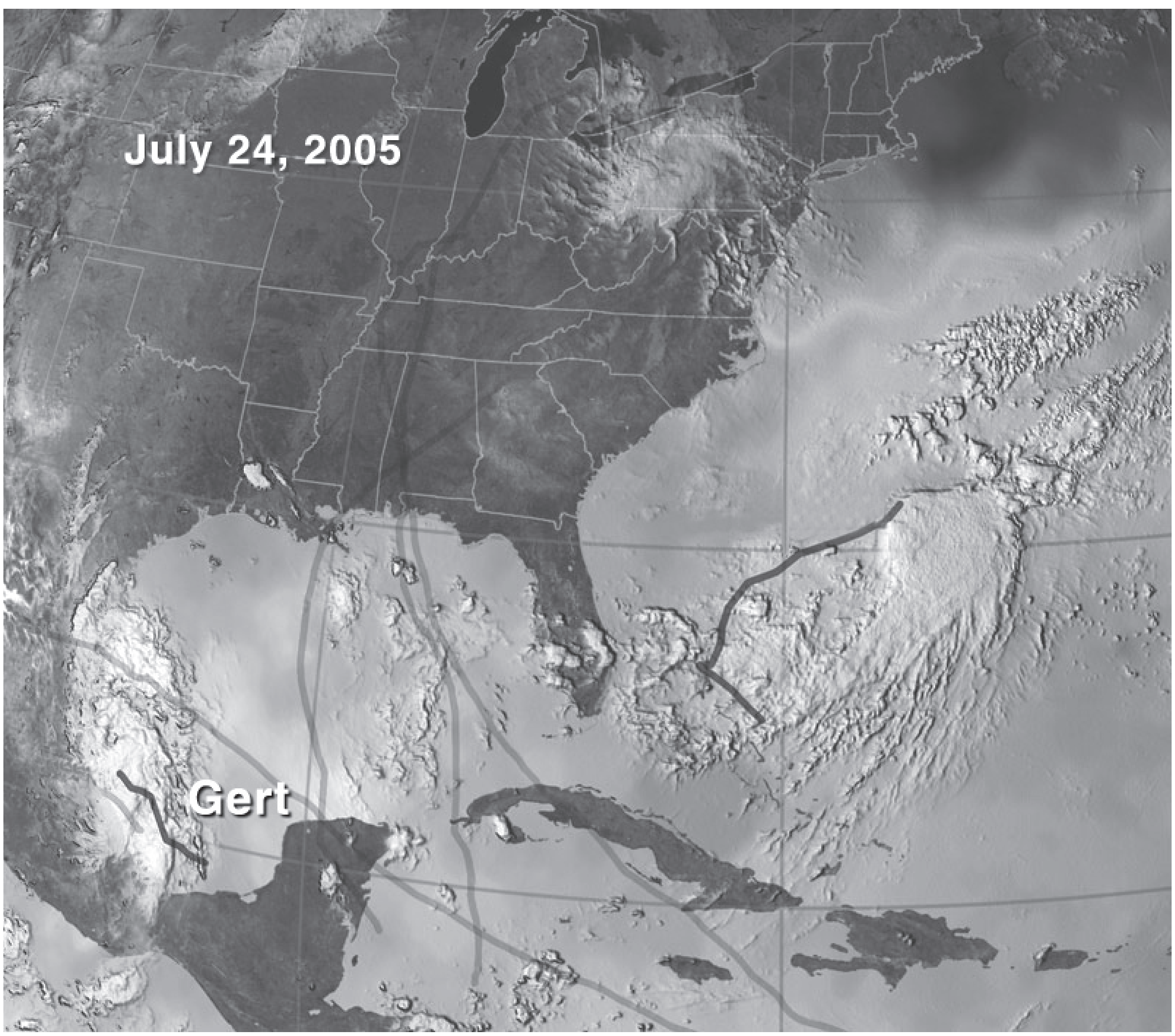
Rob Gutro, rgutro@pop900.gsfc.nasa.gov, NASA Goddard Space Flight Center

To figure out how something mechanical works, people take it apart and look at its components, then try to put it back together. That's what NASA researchers are doing with hurricanes, to try to figure out what makes them tick. For Tropical Storm Gert, which formed in the Gulf of Mexico in July 2005, they found that the mountainous areas of Mexico helped the storm to form.

To see how a hurricane works, scientists take readings of all its "pieces:" wind, rain, temperature, humidity, and air pressure. They can also use computer models to try to re-create the storm's conditions. By comparing model simulations to actual observations of the storm, they can determine how good or bad the models are. If the models do poorly, scientists try to figure out what went wrong. If they do well, scientists can then use the model results to try to better understand how hurricanes form and intensify. Researchers did this after the summer of 2005, using Gert as a test case to make sure that their computer models were accurately "re-assembling" the storm as it appeared.

Scott Braun, atmospheric scientist at NASA's Goddard Space Flight Center, Greenbelt, Md. and his co-author on the Gert study, **Michael T. Montgomery,** an atmospheric scientist from Colorado State University, took data produced by the National Centers for Environmental Prediction about the state of the atmosphere during Gert, and used it in their computer model. The model produced a re-creation of Tropical Storm Gert. Their conclusions were pre-

This image from July 24, 2005 shows the short track of Tropical Storm Gert in the lower left-hand corner of the image. Gert was located north of the Yucatan Peninsula, in the Bay of Campeche. Image credit: NASA



NASA's ER-2 airplane departs the San Juan Santa Maria airport during the TCSP mission. Image credit: NASA/Bill Ingalls

sented at the American Meteorological Society's 27th Conference on Hurricanes and Tropical Meteorology the week of April 24, 2006, in Monterey, Calif.

If one used only actual observations to figure out what makes a storm tick, it would be much more difficult because these observations are very limited in space and time. If scientists can trust that a computer model did a good job, they can use the model's information to figure out what is happening everywhere in the storm at all times. This will help scientists learn much more than they could from the observations alone.

The Gert data were gathered by a large mission called the Tropical Cloud Systems and Processes Experiment, (TCSP), which included airplanes that dropped sensors called *dropsondes* into the storminess of Gert to get wind, temperature, and humidity data. Other data used to check the accuracy of the computer model include flight-level winds from the NOAA P-3 aircraft, NASA ER-2 Doppler radar data, and precipitation information from a direct overpass of the Tropical Rainfall Measuring Mission satellite.

Gert began as a low pressure area that formed in the Gulf of Honduras just east of Chetumal, Mexico on July 22. The low quickly moved inland over Yucatan, then into the Bay of Campeche early on the 23rd. A tropical depression formed July 23 about 255 nautical miles east-southeast of Tuxpan, Mexico. The depression strengthened into Tropical Storm Gert on July 24.

"We examined the role that topography in Mexico played in the development of Tropical Storm Gert," said Braun. They found that the mountains blocked the flow of air at low levels which, according to the computer model, was critical in helping Gert form. As the weak disturbance that eventually became Gert moved into the Gulf of Mexico, the easterly winds associated with it ran up against the mountains of Mexico along the western side of the Gulf. When air flow like this encounters such an obstacle, it has two options. Under the right atmospheric conditions, air flow could simply go up and over the mountains. However, under other conditions (when the air is stable), the air encounters more resistance to upward movement and is forced to move around the mountains, creating rotation. That is what happened in Gert's case. As the easterly winds hit the mountains, they were forced to turn to the southeast in a direction parallel to the mountains. By turning the flow partially back in the direction from which it came, the mountains increased the large-scale rotation of the winds over the Gulf, thereby providing a more favorable environment for Gert to form and intensify.

This may not necessarily apply to all storms in the Gulf. Gert was probably a borderline storm that needed help to form. While some systems like Gert may occasionally need help to develop, many other storms do not require such help, but can develop easily on their own. Scientists don't know how often storms might need this type of help. Even if it is not often, knowing how those kinds of storms develop is still important to those people who are impacted by them.

For more information about the Tropical Cloud Systems and Processes Experiment on the Web, visit: *tcsp.nsstc.nasa.gov/tcsp/*

NASA Data Combined to Improve Hurricane Landfall Forecasts

Rob Gutro, rgutro@pop900.gsfc.nasa.gov, NASA Goddard Space Flight Center

Data gathered from last year's NASA hurricane research mission and a NASA satellite have improved tropical storm landfall and storm-strength forecasts in computer models.

Ocean-surface wind data gathered from NASA's Quick Scatterometer (QuikSCAT) satellite were combined with data from aircraft sensors dropped into tropical storms and fed into a new-generation weather research and forecasting (WRF) computer model used to predict weather. The researchers in this study also used data from the National Oceanic and Atmospheric Administration's (NOAA) GOES-11 satellite rapid-scan cloud-track wind data. When the data were added, the resulting prediction showed improved track and intensity forecast of tropical storms.

"Our results indicate a positive impact of those data on forecasts of two landfalling storms in last season: tropical storms Cindy and Gert." said **Zhaoxia Pu**, scientist at the University of Utah, Salt Lake City, and lead researcher on the study. She reported the results on April 24 at the American Meteorological Society's Conference on Hurricanes and Tropical Meteorology in Monterey, Calif. The detailed results of this study have been submitted to *Monthly Weather Review* for publication.

"By incorporating the aircraft sensor and QuikSCAT data, the new generation WRF computer model was able to reproduce the structure of the rainfalls that caused the flooding during the landfall of two storms," Pu said.

In July 2005, the Tropical Cloud Systems and Processes (TCSP) mission investigated two hurricanes and several tropical storms. The mission was based at the Juan Santamaria Airfield in San Jose, Costa Rica, and flew 13 NASA ER-2 science flights, including missions to Hurricanes Dennis and Emily. NASA, NOAA, and the Costa Rican Centro Nacional de Alta Tecnologia were participants in the mission.

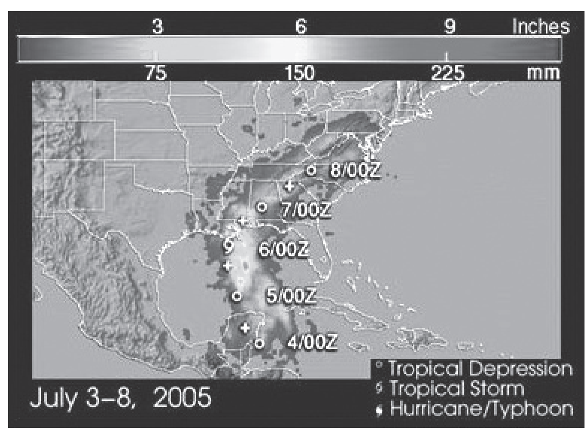
The P-3 aircraft from the NOAA Hurricane Research Division flew 20 coordinated missions with the NASA research aircraft to investigate developing tropical disturbances. Sensors called *dropsondes*, dropped from airplanes, gathered data on temperature, winds, pressure and humidity inside the storms.

The team also employed small, unmanned aerial vehicles, a series of balloon-borne weather probes, and several low-Earth, polar-orbiting and geostationary NASA and NOAA satellites.

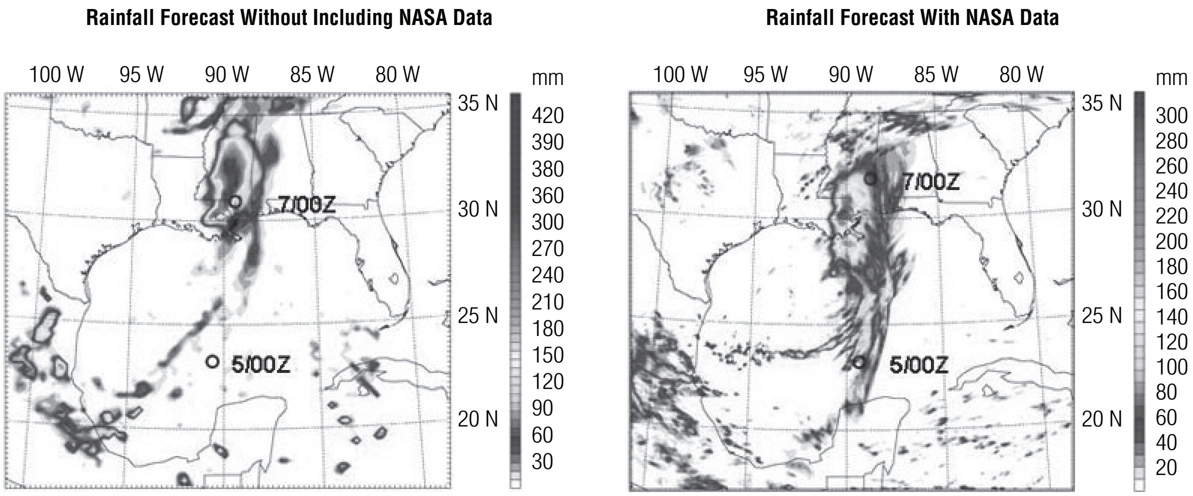
The results from this study imply that satellite data are a valuable source for improving tropical cyclone forecasts. In addition, the 2005 field experiment provided valuable data and opportunities for better understanding tropical cyclones.

The new-generation WRF computer model is widely used for forecasting and research. Many local government agencies, research-institutes and commercial industries have already used the WRF to make real-time forecasts.

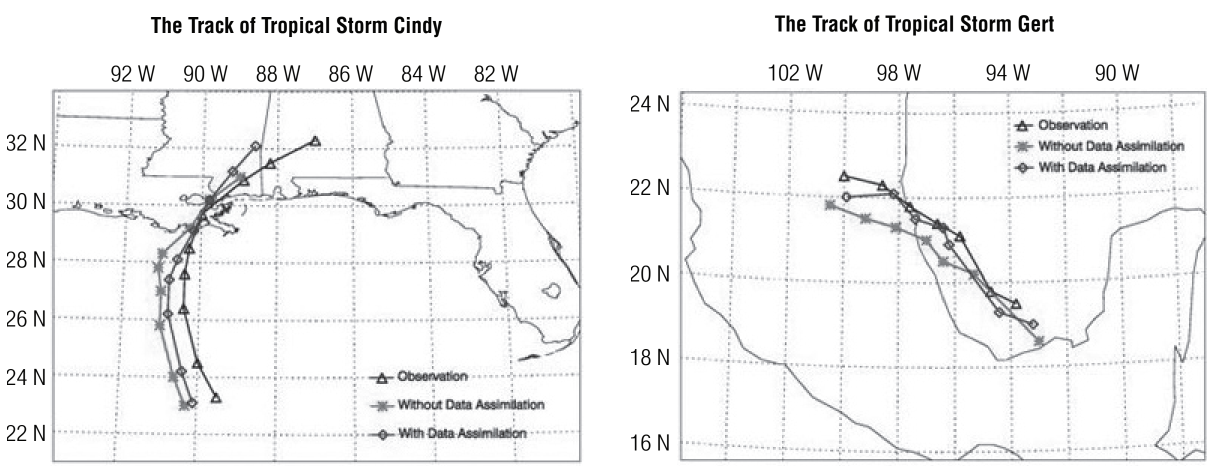
Pu said that NASA data's enhancement of WRF hurricane computer-model forecasts will encourage the forecast community to incorporate it in all future hurricane forecasts.



This image shows how much rain fell as measured on the ground along the track of tropical storm Cindy during July 3-8, 2005. Credit: NASA



NASA data helps improve the accuracy of hurricane rainfall forecasts. These two images show forecast rainfall amounts over 48 hours, from tropical storm Cindy, July 5-7 without (left) and with NASA data (right). The left image without aircraft sensor and satellite data shows unrealistically large amounts of rain after Cindy made landfall. It also missed a large amount of rainfall that happened before Cindy's center made landfall. The right image with aircraft and NASA satellite data is much more accurate in capturing the rain that actually fell. Credit: University of Utah



NASA data also helps improve the accuracy of hurricane track forecasts. These are computer model forecast tracks for tropical storms Cindy (left) and Gert (right) from July, 2005. The curve with triangle shapes is the actual track. The curve with stars represents the forecast track without NASA data, and the curved track with diamond shapes includes NASA data. The shapes along the lines indicate storm locations every 6 hours. These figures show that by adding aircraft dropsonde (sensor) data and satellite wind data, the computer model forecasts more accurate landfall times and locations and improves the storm track by about 50%. Credit: University of Utah

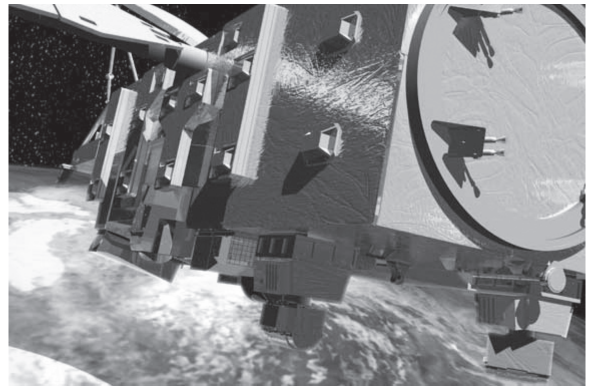
News from the CERES Team

Katherine E. Lorentz, NASA Langley, k.e.lorentz@larc.nasa.gov

With more than eight years of operation, the Clouds and the Earth's Radiant Energy System (CERES) instruments aboard the Aqua, Terra, and the Tropical Rainfall Measuring Mission (TRMM) satellites continue to measure the Earth's energy balance for a better understanding of global climate change. Observations from CERES help scientists answer longstanding questions regarding the radiative effects of clouds and the accuracy of climate models. During the past year, the CERES Science Team finished developing the most accurate method ever to convert measured radiances to fluxes for climate studies, and they released several new data sets to the public. The team released three years of new data from Terra that fundamentally redefine the Earth's radiation budget for the first time since the Earth Radiation Budget Experiment (ERBE) in 1988. The new CERES data products include the most accurate estimates yet produced of the radiative energy at the surface of the Earth.

NASA launched the first CERES instrument aboard TRMM in November 1997. Results of the TRMM mission show that this first CERES provided better measurement capabilities than any previous satellite instrument of its kind. Two additional CERES instruments on Terra—launched in 1999—and two more on Aqua—launched in 2002—are providing global coverage of energy radiated and reflected from the Earth. Two instruments are used on each spacecraft: one to map the spatial distributions of radiation and one to measure the highly variable changes in radiation with sun angle and viewing angle from space. Scientists are using measurements from both satellites to improve observations of the daily cycle of radiant energy. Newly developed CERES algorithms also provide surface dosages of ultraviolet radiation—both UVA and UVB—which are of interest to bio-medical researchers. One additional CERES instrument is available and is expected to fly as the first member of the next generation of highly accurate Earth radiation budget measurements, which are expected to result from the instruments that are part of the National Polar-orbiting Operational Environmental Satellite System [NPOESS], starting around 2011.

The CERES data products include radiative fluxes at the Earth's surface and within the atmosphere. The Web-based CERES ARM Validation Experiment (CAVE) validates the surface fluxes with independent ground-based measurements made by the Department of Energy (DOE), the National Oceanic and Atmospheric Administration (NOAA), and international teams via the World Climate Research Program's (WCRP) Baseline Surface Radiation Network (BSRN).



The CERES instruments aboard the Aqua satellite

CAVE now provides more than 5 years of validation for these CERES products. Users can run—on line—the same radiative-transfer codes that CERES employs. For the critical solar flux reaching the Earth's surface, CERES has a mean bias of a mere 4 W/m^2 (out of 1000 W/m^2 incoming at top of the atmosphere) for a 3-year record at the premier DOE surface-measurement site in Oklahoma.

The very successful ERBE mission provided the foundation for the design of the CERES instrument. Managed by Langley, ERBE used three satellites to provide global energy measurements from 1984 through the 1990s. The TRW Space & Electronics Group in Redondo Beach, California, built all six CERES instruments. The CERES project is a part of NASA's Earth Observing System (EOS) program. Data are available through Langley's Atmospheric Sciences Data Center (ASDC).

CERES and ERBE Data Confirm Recent Climate Variability, Disprove Albedo Changes Estimated from Lunar Earthshine

CERES scientists have revised and extended the reported decadal variability of the tropical mean Earth Radiation Budget with the latest ERBS Nonscanner data. The new data indicate that more net radiative energy entered the Earth's tropical climate system in the 1990s than in the 1980s. Using the same data set and the latest CERES Terra data, CERES scientists compared the recent climate variability seen in the time series of global Earth radiation budget measurements at the top of the atmosphere with an independent data set obtained from the time series of global ocean heat-storage observations. The large interannual variations do not appear to be linked to human activities, but represent a linkage between interannual variations in cloud radiative forcing and ocean heat-storage. Scientists are currently working to expand the current records of global radiation budget and global ocean heat storage measurements. These long-term climate records will play a critical role for evaluating and improving climate models.

The first four years of CERES global albedo measurements have disproved a surprisingly large relative change of 6% indicated by astronomical measurements of earthshine. Earth's *albedo* is the fraction of incident solar radiation that the planet reflects back to space. *Earthshine* is sunlight reflected from the Earth, out to the moon, and then reflected from the lunar surface back toward Earth. The large increase in Earth's global albedo inferred from earthshine should have caused a large cooling from 2000 to 2003, even larger than the effect of the Mt. Pinatubo eruption in 1991. But the Earth continues to warm globally, and the CERES data confirmed that the Earth's albedo had shown a relative decrease of less than 1%, not the earthshine-inferred 6% increase.

Terra Data Fusion

The first Terra Data Fusion and Intercomparison Meeting was held August 15–17, 2005, and included researchers, science team members, and principal investigators from the CERES, Multiangle Infrared Spectroradiometer (MISR), and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments. Terra has collected five and a half years worth of continuous data from five well-functioning instruments, and this conference was the first major meeting devoted solely to data fusion. Bringing together data from these three instruments will provide more thorough information on climate, aerosols and sea ice. In the near future, when the team explores opportunities to integrate data from the other two instruments, Measurements Of Pollution in the Troposphere (MOPITT) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), into a fused data product, they will gain more insight into air quality, atmospheric chemistry, and glaciers.

The data fusion meeting was an opportunity for the CERES science team to share some of their lessons learned to the other teams, and to explore new ideas in particularly challenging areas like the Earth's polar regions. While they have been sharing the same space-based instrument platform for the past five years, members of the different teams are only just now beginning to really get to know each other, something that will really help the process of collaboration and data fusion. Terra, NASA's Earth Observing System (EOS) flagship satellite, was launched on December 18, 1999, and is designed to improve understanding of the movements of carbon and energy throughout Earth's climate system. Furthering the idea of data fusion, a special edition of the *Journal of Atmospheric Sciences* was released in 2005 with 12 papers documenting the Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS) field campaign. CLAMS brought together CERES, MISR, and MODIS teams to improve the remote sensing of aerosols and their direct forcing of the Earth's Radiation Budget. CERES led the CLAMS campaign, during which, seven aircraft focused on the unique CERES Ocean Validation Experiment (COVE) sea platform off the coast of Virginia Beach, Va. CLAMS established the accuracy bounds of current EOS algorithms for aerosol sensing, pointed ways to improve them—including CERES fluxes—and served as a test-bed for the application of a new generation of sensors, i.e., photopolarimeter and Fourier Transform Spectrometer, for aerosol sensing.

The direct aerosol forcing to climate, which is estimated by a number of models and satellite programs globally, involves both scattering and absorption. CLAMS showed that observations from a battery of satellite, aircraft, and surface-based sensors can be used with radiative-transfer theory to provide a fairly consistent description for the effect of aerosols on the scattering of sunlight. However, the absorption component is significant at the surface and for clouds, and remains uncertain. All-in-all, CERES has been pioneering data fusion for the last eight years starting with the TRMM mission, as the eight-dimensional nature of measuring the Earth's radiation energy balance requires it.

For more information on CERES, see: *asd-www.larc.nasa.gov/ceres/ASDceres.html*

Smoke Gets In Your Eyes: AIRS Monitors Global Impacts of Pollution

Alan Buis, JPL Media Relations, alan.d.buis@jpl.nasa.gov

The first analysis of a key atmospheric pollutant obtained from the Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua satellite is shedding new light on how natural and human-produced pollutants can have wide-reaching effects on the health of our global village. The AIRS instrument has been making highly accurate measurements of air temperature, humidity, clouds, and surface temperature since 2002, but recently scientists have been able to gain valuable new information on key trace gases by taking advantage of AIRS' large number of spectral channels.

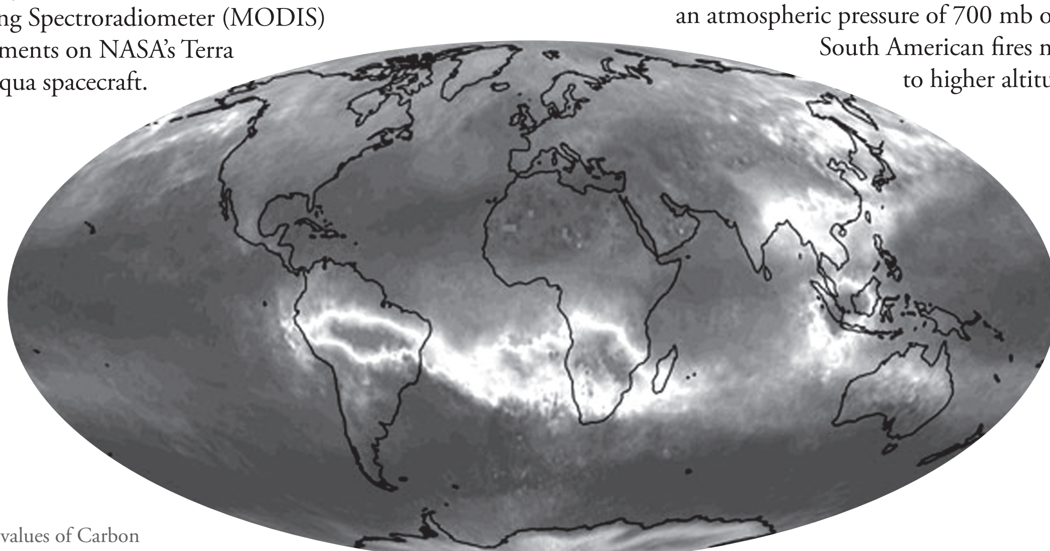
Scientists from NASA, the National Oceanic and Atmospheric Administration (NOAA) and the University of Maryland Baltimore County (UMBC) analyzed AIRS data on carbon monoxide (CO) levels in Earth's lower atmosphere, or *troposphere*, over eight days in September 2002. Carbon monoxide is a major precursor for the formation of tropospheric ozone (O_3), a very unhealthy pollutant. The results, published in the journal *Geophysical Research Letters*, demonstrate the promise that AIRS holds over the course of its seven-year lifetime for helping scientists better understand how CO is formed, how it is transported globally, and how it interacts with other chemicals to affect global air quality.

In collaboration with **Wallace McMillan** [UMBC Joint Center for Earth Systems Technology] as well as **Chris Barnet** NOAA National Environmental Satellite, Data and Information Service (NESDIS)], the scientists focused on a major South American fire event that took place September 22-29, 2002, as was detected from space by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on NASA's Terra and Aqua spacecraft.

While some of the individual fires occurring during the event resulted from natural sources, the majority resulted from human-produced biomass burning, a commonplace land-clearing practice during the dry season in the Southern Hemisphere every September and October. These fires generated a large plume of carbon monoxide that drifted across the Atlantic and Africa and reached as far as the southern Indian Ocean. Other Southern Hemisphere fires occurring at the same time in Africa and Borneo likely added to the CO plume. The AIRS CO data reveal a similar pattern of carbon monoxide global transport as had previously been detected during NASA's Transport and Atmospheric Chemistry near the Equator—Atlantic and Southern African Regional Science Initiative field experiments in 1992.

Meanwhile, in the Northern Hemisphere, AIRS detected elevated CO values over central and eastern Siberia, the northern Pacific Ocean and along the coast of southeast Asia, that could be ascribed to biomass burning, long-range transport, and industrial and domestic fuel sources, respectively. Enhanced CO values in southern Siberia resulted from a large number of fires stretching into northern Mongolia. The subsequent AIRS daily maps tracked this CO feature as it moved to the east, ending up off the west coast of northern North America. The sparse number of fires counted by MODIS over southeast Asia suggests the CO plume stretching from there to the east across the Pacific Ocean originated from industrial and domestic biofuel sources.

The study showed that the global transport of CO was highly influenced by atmospheric conditions over and downwind from pollution sources. Pollutants released at an atmospheric pressure of 700 mb over the South American fires moved to higher altitudes



Average values of Carbon Monoxide at 500 mb as measured by AIRS on Aqua, September 22-29, 2002.

and were rapidly transported west and south past Africa and on to the Indian Ocean. However, pollutants that were released at a lower atmospheric pressure of 500 mb were recirculated within the South Atlantic and transported upward in the atmosphere to an atmospheric pressure of 300 mb.

"Never before have such detailed views of a tropospheric trace gas, other than water, been available on a daily basis," writes McMillan. " AIRS represents a significant evolutionary advance in satellite trace-gas remote sensing. For the first time, we will be able to monitor the daily changes in the globe encircling transport of biomass burning emissions heretofore seen only in computer models."

"On a global basis, nearly 50% of CO emissions originate from human-produced sources, with the remainder resulting from biomass burning and oxidation of naturally occurring volatile hydrocarbons," said McMillan. "CO levels can be viewed as indicative of the state of Earth's carbon cycle and global climate change," McMillan said. "In addition, CO has a one- to three-month lifetime in the troposphere, making it an excellent way to track motions of the atmosphere and the variability of pollution sources. As a precursor for the formation of tropospheric ozone and smog, global CO observations from AIRS and other NASA instruments are crucial for modeling tropospheric chemistry and assessing the overall health of our atmosphere."

For nearly a quarter century, NASA has used innovative Earth-orbiting instruments to glean new insights into air quality issues. The first global views of CO came from the 1981 flight of NASA's Measurement of Atmospheric Pollution from Space (MAPS) instrument aboard the Space Shuttle. That experiment, which was subsequently reflown aboard the Shuttle in 1984 and 1994, had a relatively small field of view and could only point directly down at the Earth below. As a result, it took a week or longer to produce a global CO map. Currently, the Measurement Of Pollution In The Troposphere (MOPITT) instrument on NASA's Terra satellite uses technology similar to that of MAPS to measure tropospheric CO. While MOPITT has much greater spatial coverage per orbit than the earlier instrument, it still requires three-to-five days to produce a contiguous global map, so daily phenomena are missed.

AIRS represents a significant advancement in the state of the art. Launched May 4, 2002, the high-spectral-resolution infrared instrument takes 3-D pictures of atmospheric temperatures, water vapor, and trace gases. It is the first in a series of advanced infrared sounders that will provide accurate, detailed atmospheric temperature and moisture observations for weather and climate applications. Orbiting Earth at an altitude of 705 km (438 mi), it views the atmosphere through nearly 2,400 different spectral channels and has a 13.5 km (8.4 mi) Earth-pointing field of view. In addition to CO, other key trace gases it monitors include CO and methane (CH_4). With a similar sensitivity to mid-tropospheric CO as the previous two instruments, AIRS' unique daily global view provides nearly 10 times as many retrievals per day as MOPITT and enables process studies of phenomena on daily timescales. Its 144,000 daily retrievals are used to create 1° latitude x 1° longitude grid maps that cover approximately 70% of the planet from 60° N to 60° S.

McMillan said that work remains to further validate the AIRS CO retrievals using aircraft measurements and comparisons with chemical transport and trajectory models. Early validation results, however, show the instrument is accurate to within 15%, achieving the level predicted in pre-launch simulations. The AIRS Science Team is currently working to produce a standard CO daily map product and is performing detailed global comparisons with MOPITT measurements.

Moustafa Chahine, [NASA/Jet Propulsion Laboratory (JPL)—*AIRS Science Team Leader*] said the team expects the routine global CO maps from AIRS will lead to a more complete understanding of the CO budget. "Along with future AIRS CO_2 and CH_4 retrievals and data from NASA's Tropospheric Emission Spectrometer (TES) on the Aura satellite, we are confident these new NASA data will provide unique insights into the global carbon cycle and global climate change."

TES, NASA's latest addition to its suite of atmospheric monitoring tools, measures CO as well as many other trace gases, allowing scientists to see where or how far away air quality is influenced by biomass burning and for how long, according to **Michael Gunson**, [JPL—*TES Deputy Principal Investigator*], TES data complements that from AIRS by providing detailed information on the chemical processes regulating global air quality. For more information about AIRS and TES on the Internet, visit: *AIRS.jpl.nasa.gov/* and *tes.jpl.nasa.gov/index.cfm.*

For more information on McMillan's research or to contact him directly: *mcmillan@umbc.eduphysics.umbc.edu/~mcmillan.*

EOS Scientists in the News

Stephen Cole, scole@pop600.gsfc.nasa.gov, NASA Earth Science News Team
Mike Bettwy, michael_bettwy@ssaihq.com, NASA Earth Science News Team

NASA Earth Science Exhibits Open in Smithsonian Museum, April 11; *Yahoo! News, SpaceRef.com.* NASA scientists including **Ernest Hilsenrath** (NASA HQ) and **Waleed Abdalati** (NASA GSFC) announce two new exhibits, *Atmosphere: Change in the Air* and *Arctic: A Friend Acting Strangely*, at the Smithsonian National Museum of Natural History in Washington that feature data on the Earth's changing climate.

Climate Change and Global Warming, April 11; *Beyond the Beltway.* **Bill Patzert** (NASA JPL) was one of several panelists on this cable television program that discussed a variety of issues surrounding climate change and global warming.

NASA Helps Researchers Diagnose Recent Coral Bleaching at Great Barrier Reef, April 5; *Reuters, ABC, BBC, CNN.* Using MODIS data, an international team of scientists, including **Gene Feldman** (NASA GSFC), is working at a rapid pace to study environmental conditions behind the fast-acting and widespread coral bleaching currently plaguing Australia's Great Barrier Reef.

Space Network to Track Rainfall, April 3; *BBC.* The upcoming Global Precipitation Measurement project, a joint mission between NASA and Japan Aerospace Exploration Agency (JAXA), will provide three-hourly reports on rainfall around the world and aims to improve weather forecasting and the understanding of how the global water cycle affects climatic change, says **Eyal Amitai** (NASA GSFC) and **Arthur Hou** (NASA GSFC).

NASA Scientists Claim Warmer Ocean Waters Reducing Ice Worldwide, March 23; *Reuters, Boston Globe, San Francisco Chronicle, St. Louis Post-Dispatch, LiveScience.com.* **Robert Bindschadler** (NASA GSFC) and **Waleed Abdalati** (NASA GSFC) say the pieces to a years-old scientific puzzle have come together to confirm that warmer water temperatures are creeping into the Earth's colder areas, melting and accelerating ice flow in polar areas.

Amazon Rainforest Greens Up in the Dry Season, March 21; *National Public Radio, Science, New Scientist.* Research conducted by **Alfredo Huete** (University of Arizona) using MODIS data found that in the Amazon rain-forest vegetation often enters a growth spurt when you least expect it: during the dry season.

With Spring, Harsh Weather Across the U.S., March 21; *NBC Today Show.* **Bill Patzert** (NASA JPL) discusses the arrival of spring and the recent rounds of harsh weather, from snow in the Midwest to rain in Texas and tornadoes across the South.

Scientists Use Satellites to Help Detect Deep-Ocean Whirlpools, March 20; *SpaceRef.com, Science Daily.* Using sensor data from several NASA and European satellites, researchers including **Timothy Liu** (NASA JPL) have developed a method to detect salty, submerged eddies called *meddies* that occur in the Atlantic Ocean off Spain and Portugal at depths of more than 1,000 meters and help drive the ocean currents that moderate Earth's climate.

Scientists in Dogged Pursuit of Amount of Snow on Earth Embark on Arctic Trek, March 17; *Quebec Daily News, Science Daily.* Seven explorers, including scientists and teachers, will mush across the Arctic through May with polar huskies to collect samples of hydro-meteorological snow data for use in validating snow-pack observations from NASA's Aqua satellite, says **James Foster** (NASA GSFC).

NASA Study Links "Smog" to Arctic Warming, March 15; *ABC, CBS, The New York Times.* **Drew Shindell** (NASA GISS) finds that a major form of global air pollution involved in summertime "smog" has also played a significant role in warming the Arctic.

New Test of Snow's Thickness May Bear Results Key to Polar Climate Studies, March 15; *Reuters, ABC, CNN, MSNBC.* From mid-March to mid-April, researchers including **Thorsten Markus** (NASA GSFC) and **Donald Cavalieri** (NASA GSFC) embarked on an Arctic field experiment involving AMSR-E data to assess snow thickness and its impact on polar bears and other wildlife.

NASA Finds Stronger Storms Change Heat and Rainfall Worldwide, March 9; *Science Daily, PhysOrg.com, Terra Daily.* Studies have shown that over the last 40 years a warming climate has been accompanied by fewer rain- and snow-producing storms in mid-latitudes around the world, but the storms that are happening are a little stronger with more precipitation, say **George Tselioudis** (NASA GISS) and **William Rossow** (NASA GISS).

NASA Survey Confirms Climate Warming Impact On Polar Ice Sheets, March 8; *United Press International, ABC, MSNBC, The New York Times, BBC.* In the most comprehensive survey ever undertaken of the massive ice sheets covering both Greenland and Antarctica, NASA scientists including **Jay Zwally** (NASA GSFC) confirm climate warming is changing how much water remains locked in Earth's largest storehouses of ice and snow.

NASA Mission Detects Significant Antarctic Ice Mass Loss, March 2; *Associated Press, Reuters, United Press International.* The first-ever gravity survey of the entire Antarctic ice sheet, conducted using data from GRACE, concludes the ice sheet's mass has decreased significantly from 2002 to 2005, according to **Isabella Velicogna** (University of Colorado) and **John Wahr** (University of Colorado).

NASA Embarks on International Study of Air Pollution Flowing Into U.S. from Abroad, March 2; *United Press International, Yahoo! News.* NASA scientists, including **Hanwant Singh** (NASA ARC) will carry out the second of a two-phase project that aims to understand the transport and evolution of gases and aerosols across continents and their impact on regional air quality and climate.

Scientists Confirm Historic Massive Flood In Climate Change, February 28; *United Press International, Science Daily, Economist.com.* **Gavin Schmidt** (NASA GISS) used computer modeling to reproduce an abrupt climate change that took place 8,200 years ago and found that climate changes were caused by a massive flood of freshwater into the North Atlantic Ocean.

Interested in getting your research out to the general public, educators, and the scientific community? Please contact Steve Cole on NASA's Earth Science News Team at scole@pop600.gsfc.nasa.gov and let him know of your upcoming journal articles, new satellite images or conference presentations that you think the average person would be interested in learning about. ■

Announcement: New Products Available from Langley's ASDC

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center announces the release of the following new products:

In collaboration with the **Fast Longwave And Shortwave Radiative Fluxes (FLASHFlux) Science Team**, ASDC has produced two new data sets that contain instantaneous near-real-time surface and Top-of-Atmosphere (TOA) radiative fluxes and related data.

- Terra CERES data sets [1]
  - FLASH_SSF_Terra-FM1-MODIS_Version1A
  - FLASH_SSF_Terra-FM2-MODIS_Version1A

ASDC has also collaborated with the **Clouds and the Earth's Radiant Energy System (CERES) Science Team** to produce Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF) data products for Aqua.

- CER_SSF_Aqua-FM3-MODIS_Edition2A
- CER_SSF_Aqua-FM4-MODIS_Edition2A
- CER_SSF_Aqua-FM4-MODIS_Ed2A-NoSW [2]

Information on these new products can be found at the following URLs:
FLASHFlux Products: *eosweb.larc.nasa.gov/PRODOCS/flashflux/table_flashflux.html;*
CERES Products: *eosweb.larc.nasa.gov/PRODOCS/ceres/table_ceres.html. 3*

[1] On Terra, FLASHFlux can choose to process either FM1 or FM2 data, and will typically choose to process data from the instrument that is in the *crosstrack* scan mode. The user should therefore be aware that a combination of CERES FM1 and CERES FM2 data may be required to obtain all the Terra CERES data for a given time period.
[2] On March 30, 2005, at approximately 18:42 UTC, the Aqua FM4 SW channel stopped functioning. To remind users of this fact, all data from that time forward are processed as *Ed2A-NoSW.*
[3] For more information on ASDC data holdings or for help in placing an order please contact the ASDC—**Mail:** Atmospheric Science Data Center, NASA Langley Research Center, Science Users and Data Services, Mail Stop 157D, Wright Street, Hampton, VA 23681-2199; **Phone:** (757) 864 8656; e-mail: *larc@eos.nasa.gov;* **URL:** *eosweb.larc.nasa.gov.*

NASA Science Mission Directorate – Science Education Update

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ESSE 21 ANNUAL MEETING, AUGUST 7-11, UNIVERSITY OF NEW HAMPSHIRE, DURHAM

The Earth System Science Education for the 21st Century (ESSE 21) Annual Meeting is an opportunity for program participants and the community at large to share ideas regarding Earth system science in the classroom, learning from each other as well as from Earth system scientists and educators, and other invited speakers. The annual three-day meeting offers formal and informal opportunities to make presentations, demonstrate capabilities and techniques, report on progress, and offer hands-on tutorials to acquaint attendees with the most recent innovations in Earth-science learning. Additional information will be available at *esse21.usra.edu/ESSE21*

OTHER ANNOUNCEMENTS

NASA TV Extra Themes
Each month a list of resources for educators is gathered to support a theme related to NASA. Visit *www.nasa.gov/audience/foreducators/topnav/schedule/extrathemes/index.html* .

NASA Express Mailing List
Join the EXPRESS Mailing list for educators to receive announcements of new NASA educational publications, NASA multimedia materials from Central Operation of Resources for Educators (CORE), and other opportunities for educators. Visit *www.nasa.gov/audience/foreducators/top-nav/mailinglist/*.

NASA Kid's Club Web site
NASA's new Kids' Club Web site, *www.nasa.gov/kids-club*, features animated, colorful educational activities for children in K-4. Interactive games teach children about exploring space, building and launching rockets, keeping airplanes on schedule and how a comet travels through the solar system.

Space Foundation Web site
The Space Foundation at *www.ScienceStandardsLessons.org* has developed a new Web site for Pre-K-12 teachers with more than 200 science lesson plans organized by grade level: Pre-K-2, 3-5, 6-8, and 9-12.

Announcement

Announcement: GLOBE Teams with National Geographic to Improve Geographic Literacy

The GLOBE Program has joined a coalition led by the National Geographic in a campaign designed to give students tools to become more informed global citizens. The goal of the five-year, multimedia campaign—*My Wonderful World*—is to improve the geographic literacy of young people ages 8-17. Specifically, the campaign aims to:

- show parents how to help their children learn about the world;
- increase geographic offerings in schools and the resources available to them;
- increase the number of students who take geography-related courses and engage in related activities in school, and
- increase the number of community organizations that engage young people in geography-related activities.

The Web site, *www.MyWonderfulWorld.org* provides resources such as suggestions for family activities and ways parents can help to get more geography into the classroom, links to geography games and online adventures, classroom materials for educators, ways to test global IQs, and tools for communicating to policymakers and education leaders the importance of geographic literacy. If you use GLOBE in your classroom, and want you and your students to become involved in *My Wonderful World*, contact *help@globe.gov.*

The GLOBE Annual Conference will be in Phuket, Thailand, July 30-August 4, with the theme "The New Decade for Global Sustainable Development." For complete details for the conference and symposium, visit *globethailand.ipst.ac.th/Annual2006*.

EOS Science Calendar

June 20-22
11th OMI Science Team Meeting, Koninklijk Nederlands Meteorologisch Instituut (KNMI), De Bilt, Netherlands. Contact: Rene Noordhoek, *R.Noordhoek@knmi.nl; URL: http://www.knmi.nl/omi/research/project/meetings/ostm11/index.html*

June 27-29
Sixth Annual Earth Science Technology Conference ESTC2006, College Park, MD. URL: *http://esto.nasa.gov/conferences/estc2006/*

July 19-21
ESIP Federation Summer Conference, Lamont Doherty Earth Observatory, Palisades, NY. Contact: Carol Meyer, *carol.meyer@earthsciencefoundation.org.*

September 18
Aura Science Team Meeting and Validation Working Group Meeting, Boulder, CO. Contact: Anne Douglass, *Anne.R.Douglass@nasa.gov*.

September 20-22
SORCE Science Team Meeting: Earth's Radiative Energy Balance Related to SORCE, Orcas Island, San Juan Islands, Washington. Contact: Vanessa George, *Vanessa.George@lasp.colorado.edu;* URL: *http://lasp.colorado.edu/sorce/2006ScienceMeeting/*

Global Change Calendar

July 3-6
ISPRS Commission I Symposium, Paris, France. Email: *isprs2006@colloquium.fr* URL: *www.colloquium.fr/sfpt2006*.

July 12-14
4th IEEE Workshop on Sensor Array and Multi-Channel Processing (SAM), Westin Hotel, Waltham, MA. URL: *www.sam2006.org*.

July 24-27
Western Pacific Geophysics Meeting, Beijing, China. URL: *www.agu.org/meetings/wp06/?content=program*

August 13-17
SPIE's Optics and Photonics 2006: Earth Observing Systems XI (OEI101) Conference, San Diego, CA. URL: *spie.org/conferences/calls/06/op/conferences/index.cfm?fuseaction=OEI101.*

September 13-15, 2006
Commercial Remote Sensing Satellite Symposium: Key Trends and Challenges in the Global Marketplace, Ronald Reagan Building, Washington, DC. URL: *www.CRSSymposium.com*

September 17-23
Joint CACGP/IGAC/WMO Symposium: Atmospheric Chemistry at the Interfaces 2006, Cape Town, South Africa. Call for Papers. Contact: *brian@globalconf.co.za*. URL: *www.atmosphericinterfaces2006.co.za/*

September 25-29
2nd International Symposium on the Recent Advances in Quantitative Remote Sensing, Torrent, Spain. URL: *www.uv.es/raqrs/index.htm*.

November 7-8
2nd International Young Scientists' Global Change Conference, Beijing, China. URL: *www.start.org/links/announce_oppo/YSC_2006_Announce7.pdf*

November 9-12
Global Environmental Change: Regional Challenges–An Earth System Science Partnership, Global Environmental Change Open Science Conference, (IGBP, WCRP, IHDP, Diversitas), Bejing, China. URL: *www.essp.org/essp/ESSP2006/*

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