



# The Earth Observer

## Editor's Corner

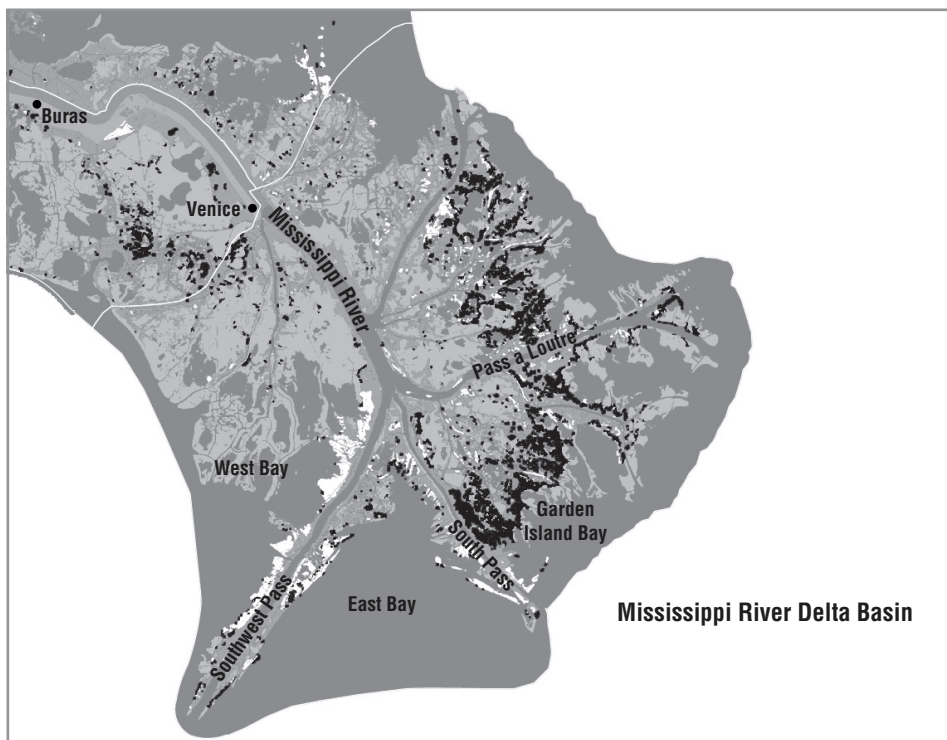
**Michael King**  
EOS Senior Project Scientist

NASA Administrator **Michael Griffin** spoke at an *All Hands* meeting at Goddard Space Flight Center on September 12. He made it very clear that he disagrees with accusations that NASA's Science program has been "decimated" as a result of recent budget cuts. Griffin's objective was to change this debate into a "more thoughtful, objective dialogue about the issues facing NASA's science and exploration programs than what has been presented in many circles, and reduce some of the angst in the community." He stressed that NASA, the Office of Management and Budget, and the President are not anti-science, and cited numerous examples including the following comments relevant to Earth science:

*"While we will still launch a mission to Mars at every orbital opportunity, we have rebalanced what many viewed as an excessive increase—about 40%—to robotic Mars exploration, at the expense of other areas in science. Further, we have restored some cuts made previously in Earth science, and sponsored a National Academy study to produce the equivalent of a 'decadal survey' in this field for the first time. **These decisions reflect a commitment by NASA to long-term***

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The U.S. Geological Survey has used Landsat data to help them assess the impact that Hurricane's Katrina (August 29, 2005) and Rita (September 24, 2005) had on the Louisiana coast. This image shows a map of Mississippi River Delta land change measuring the difference between land-water area before the storms (2004) and land-water area after the storms (2005). The darker region highlights the land lost. The land-water area before the storms was assessed using a series Landsat Thematic Mapper images acquired between October 13 and November 7, 2004. A series of seven TM scenes acquired between October 16 and October 25, 2005, provided a snapshot of land-water area changes after the storms. The 2004 and 2005 datasets were matched to the 1956 data covering the common area of the Louisiana Coastal Zone Boundary (CZB) and Louisiana Coastal Area (LCA) to ensure compatible comparisons between datasets. **Credit:** John A. Barras, USGS. [See [pubs.usgs.gov/of/2006/1274/](http://pubs.usgs.gov/of/2006/1274/) for full article.]



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In other NASA Headquarters news, I'm pleased to announce that, as of October 23, **Michael Freilich** assumed the role of Director of the Earth Science Division at NASA Headquarters. Freilich was most recently an associate dean in the College of Oceanic and Atmospheric Sciences at Oregon State University and currently serves as the Principal Investigator for the SeaWinds instrument on NASA's Quick Scatterometer (QuikSCAT) mission. He received his Ph.D. in oceanography from Scripps Institution of Oceanography in 1982, and joined the Jet Propulsion Laboratory in 1983 as a member of the oceanography group. He has served as the Project Scientist, Principal Investigator, or Science Team Leader for the NSCAT, QuikSCAT, and SeaWinds/ADEOS-2 scatterometer missions. For his pioneering development and scientific application of satellite scatterometry as an essential oceanic tool, he received the Verner E. Suomi Award of the American Meteorological Society in 2004. Freilich has also served on the NRC Ocean Studies and Space Studies Boards, and the Committee on Earth Studies. I congratulate Freilich on his appointment and wish him success in his new position.

I'm happy to announce that **N. Christina Hsu** has been appointed Deputy Project Scientist for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) Mission. She will replace **Jeffrey L. Privette** who recently moved to NOAA's National Climate Data Center. Privette has served as NPP Deputy Project Scientist since 2002, and also was the Instrument Scientist for the Visible Infrared Imager Radiometer Suite (VIIRS), a 22-band wide field-of-view sensor slated for NPP and NPOESS that will succeed the Moderate Resolution Imaging Spectroradiometer (MODIS). He has also served on the VIIRS Operational Algorithm Team for the NPOESS Integrated Program Office since 1997. Privette's contribution to the NPP Mission is greatly appreciated and I wish him luck in his new position at NOAA.

Hsu is a member of the Earth Observing System's MODIS, Clouds and the Earth's Radiant Energy System (CERES), and Total Ozone Monitoring Spectrometer (TOMS) Science Teams, where her focus is on the properties of aerosols in both the ultraviolet and visible spectrum, and determination of the radiative forcing due to tropospheric aerosols. Her research experience includes aerosol-climate interaction studies and development of near-real-time satellite retrievals of aerosols using the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and MODIS measurements over land and ocean for field campaigns. Her *Deep Blue* algorithm for retrieving aerosol optical properties over bright desert surfaces and urban environments is widely recognized and is of enormous interest to NASA, NOAA, and the Department of Defense. The *Deep Blue* algorithm provides crucial information in modeling the atmospheric

**balance in our science portfolio, and recognition of the key role of Earth science in that portfolio.** *Earth science at NASA receives \$1.5 B annually, more than 25% of our science portfolio.*"

Griffin's full speech can be viewed at: [www.nasa.gov/pdf/157382main\\_griffin-goddard-science.pdf](http://www.nasa.gov/pdf/157382main_griffin-goddard-science.pdf).

contribution to the signals received by satellite sensors, leading to the substantial improvement of accuracy of the land and ocean color products retrieved by satellites.

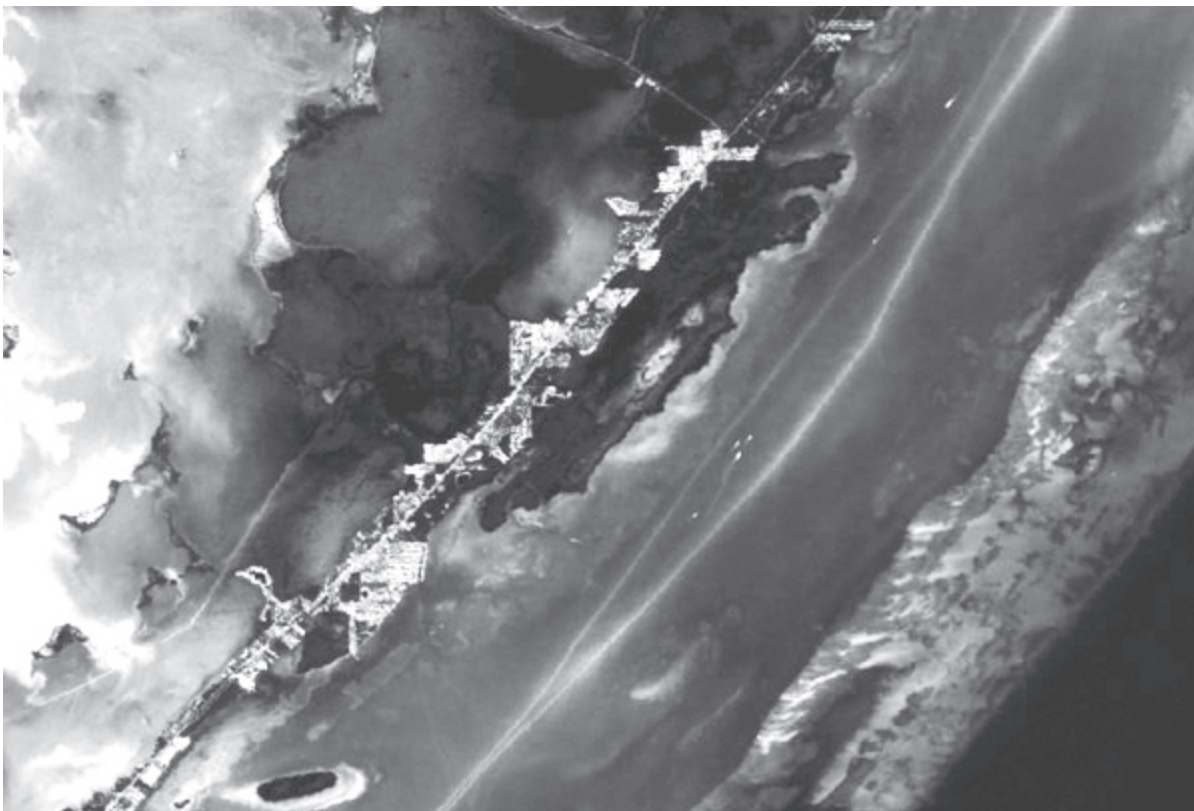
Hsu's experience with operational algorithms with TOMS, SeaWiFS, and MODIS are directly relevant to the role of assessing the algorithm readiness and performance of the industry-provided algorithms to be executed by NPP and the follow-on NPOESS program. I am certain that Hsu will do an outstanding job in her new role and I look forward to working with her on the development of NPP and NPOESS.

I'm happy to report that the U.S. Geological Survey (USGS), in cooperation with NASA, has announced the selection of the LDCM Science Team. These scientists and engineers will advise the USGS and NASA on issues critical to the success of the LDCM. Landsat 7 Project Scientist **Darrel Williams** [Goddard Space Flight Center (GSFC)] and co-investigator **Samuel N. Goward** [University of Maryland, College Park] have received a five year award under the title *The Landsat Data Continuity Mission (LDCM) Long-Term Acquisition Plan (LTAP): Extending and enhancing the Landsat 7 LTAP approach*. Their proposed LDCM Science Team

activity will be based on the experiences they gained over the last decade in developing and validating the L7 LTAP. **Bob Bindschadler** [GSFC] former Landsat 7 Science Team member, has also been selected as an unfunded federal PI. Other former Landsat 7 Science Team members who were selected include **John Schott** [Rochester Institute of Technology], **Dennis Helder** [South Dakota State University], **Curtis Woodcock** [Boston University], and **Jim Vogelmann** [USGS Earth Resources Observation Systems]. A complete list of selectees can be viewed at [landsat.gsfc.nasa.gov/news/news-archive/news\\_0036.html](http://landsat.gsfc.nasa.gov/news/news-archive/news_0036.html). The LDCM will have a 5-year mission life with 10-year expendable provisions. As with previous Landsat missions (save Landsat 6), NASA will build and launch LDCM. Then, following a prescribed on-orbit verification period, NASA plans to transfer ownership of the observatory and the associated contracts to the USGS, which will then operate the spacecraft and manage the data.

Lastly, as we draw to the end of another exciting year for Earth science at NASA, I would like to take this opportunity, on behalf of the entire staff of *The Earth Observer*, to wish everyone a Happy and Safe Holiday Season. ■

Shown here is a Landsat-7 Enhanced Thematic Mapper Plus image of a coral reef near Key Largo, Florida. NASA satellite data were used to help monitor the health of Florida's coral reefs as part of a field research effort completed this August and September. The recently developed Landsat-based Millennium Coral Reef Map was used to help the researchers determine which reef areas were most appropriate for sampling. Sea surface temperature (SST) is an important indicator of coral reef health. So in addition to Landsat, researchers used data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua to give them up-to-date information on sea surface temperature and heat buildup over several weeks—areas with higher SST and enhanced heat buildup are areas vulnerable to coral bleaching. **Credit:** NASA/GSFC [See [www.nasa.gov/centers/goddard/news/topstory/2006/coral\\_health.html](http://www.nasa.gov/centers/goddard/news/topstory/2006/coral_health.html) for full article.]



# The Past, Present, and Future of the Landsat Program

Alan Ward, NASA Goddard Space Flight Center, [award@sesda2.com](mailto:award@sesda2.com)

For additional information on this topic, please see the October 2006 special issue of *Photogrammetric Engineering & Remote Sensing (PE&RS)* [Volume 72, Issue 10, pp 1171 - 1178] devoted to Landsat. The article is entitled, "Landsat: Yesterday, Today, and Tomorrow," and is written by **Darrel Williams** [NASA Goddard Space Flight Center (GSFC)—Landsat 7 Project Scientist], **Samuel N. Goward** [University of Maryland College Park], and **Terry Arvidson** [Lockheed Martin]—see **Table 1** for a summary of articles in this Landsat special issue.

## Introduction

Approximately 40 years ago, William T. Pecora had a dream. In a decade when most of the space industry and science community was focused on getting man to the moon and exploring the universe beyond, Pecora felt that perhaps we ought to use some of the new technolo-

gies to look at our own planet more closely and see how Earth is influenced by natural events and human activities. What evolved from that dream is what we know today as the Landsat series of Earth observation satellites.

Early experiments in Earth imaging from space had convinced Pecora and other scientists that detailed imaging of the Earth's land area from space was possible. By the late 1960s both the Department of Interior (DOI) and NASA were involved in planning an Earth observation mission. The launch of the Earth Resources Technology Satellite (ERTS) in 1972—which later became known as Landsat 1—ushered in the modern era of terrestrial satellite remote sensing, and pioneered the use of space platforms for systematic collection of land images. For the first time, scientists had the capability to take repetitive measurements of the same region and could study how the region changed over time. Landsat

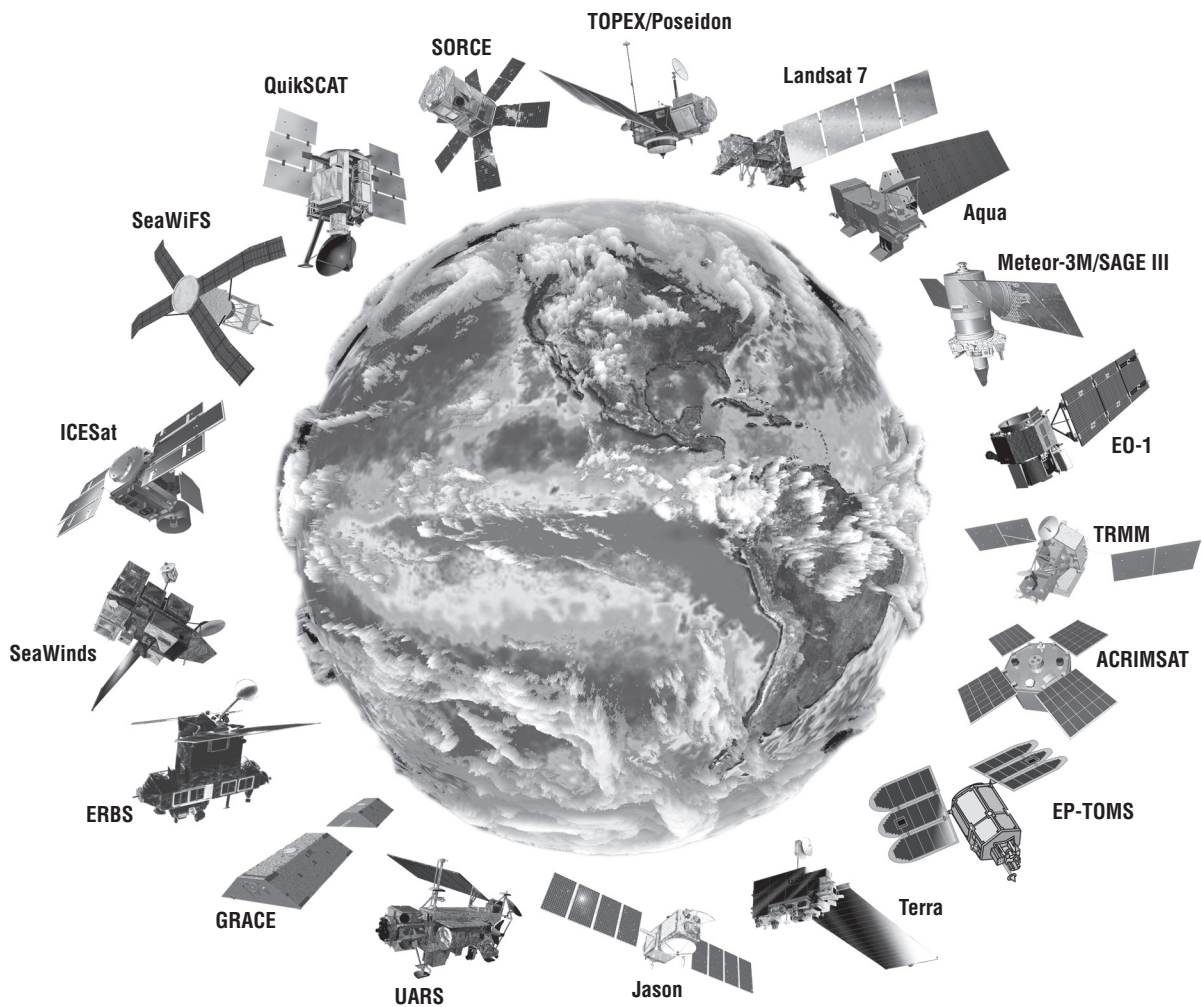
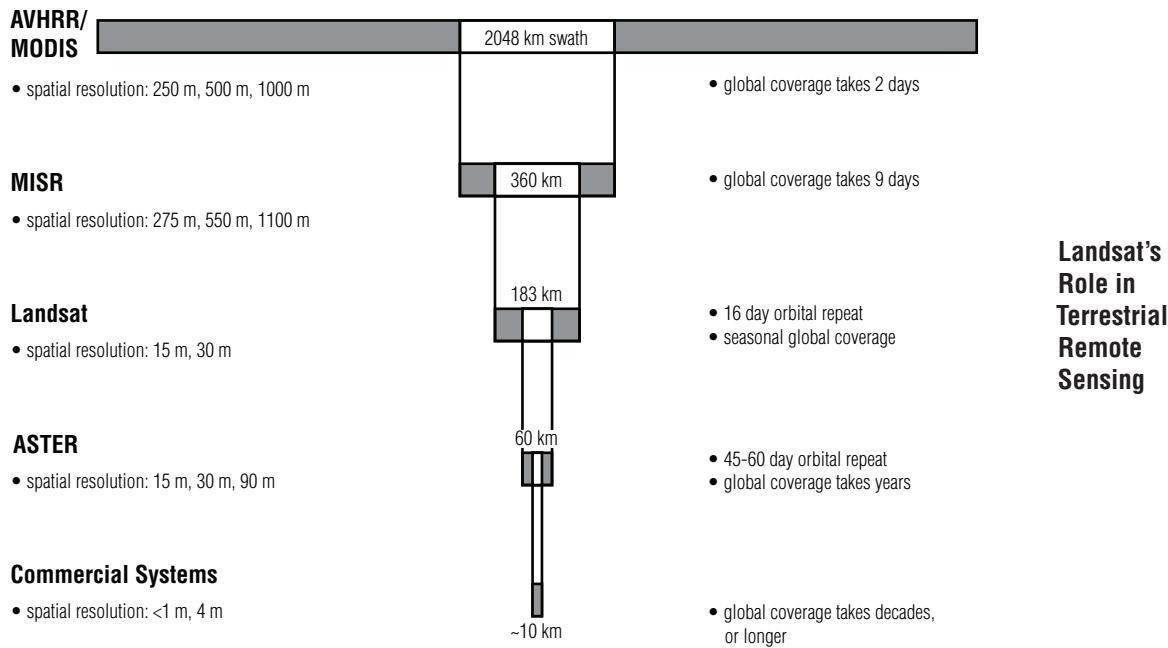


FIGURE 1: Some of the more than 40 Earth-observing satellites launched since Landsat 1.



**FIGURE 2:** Landsat's medium resolution is well-suited to systematic global coverage at a scale where both natural or man-induced changes can be observed.

provided medium-to-high resolution, *multispectral* images—meaning that they were detailed images viewed in several different visible and infrared wavelengths—and these new Earth observing capabilities led to a virtual revolution in terrestrial research capabilities. Researchers could monitor biospheric processes from space and could track the seasonal and interannual evolution of land cover conditions anywhere on the globe. Since the launch of Landsat 1, nearly 40 other Earth-observation missions have been launched or planned internationally—see **Figure 1**—a testament to the overall success and importance of the Landsat program.

### The Role of Landsat in Shaping Earth System Science

Over the last quarter century, scientists have increasingly focused on understanding Earth's environmental systems. Measurements of atmospheric chemistry and models of global climate suggest that changes have occurred in the Earth system over the past century, that these changes continue today, and that these changes may alter environmental conditions over the next century. To fully assess the impact that these changes will have on Earth's future climate, scientists must understand how the various elements of the Earth system (i.e., climate, water cycle, carbon cycle, and human activities) interact with one another to produce environmental conditions. Such an integrated, interdisciplinary approach to studying Earth's environment is known as *Earth systems science*.

Landsat was one of the major forces leading to the development of the global-scale Earth systems science concept. In order to study the Earth as a single integrated system it is necessary to collect measurements of all

the various elements of the system at frequent intervals on a consistent basis over the entire globe—**Figure 2**. In the mid-1980s, after a decade of Landsat research, it became evident that, from their vantage point in space, Earth observing satellites offered a unique capability of fulfilling all those requirements at once.

Early research results showed that Landsat was capable of measuring key physical and biological processes that describe how land conditions modulate the Earth system. This led to the development of fully integrated land-ocean-atmosphere monitoring and modeling. Landsat image data now provide one of the most important elements of Earth observation data needed to understand Earth as an integrated system.

### The Politics of Landsat, Part 1: A Tumultuous Past

Despite the important role Landsat missions have played in Earth observations and the development of Earth system science over the years, the program has experienced its share of external stresses. NASA originally developed Landsat to demonstrate new technologies, and the technologies succeeded well beyond anyone's expectations, but because of that, Landsat seemed to struggle to find a comfortable operational home. The high quality of the early images returned from Landsat made many people feel that Landsat had significant commercial value, and should be turned over to the private sector—as was common for communication satellites of that era. In 1984, Congress directed NOAA to transfer control of the Landsat program to a private company. The Earth Observation Satellite Company (EOSAT) was awarded a 10-year contract to take control of the Landsat 4 and 5 missions, and to build Landsat 6 and 7.

The ensuing decade was beset with problems for the Landsat program; however, privatization led to substantially increased data costs, limited global acquisitions, severe data exchange constraints, and culminated in EOSAT's failure to place Landsat 6 in Earth orbit. Not long after that failure, in 1992, Congress directed that the Landsat program, including the building of Landsat 7, be returned to Federal Government management. NASA, NOAA, and the U.S. Geological Survey (USGS) have been actively involved in the Landsat program since the early '90s. NASA ultimately built and launched Landsat 7 and then turned over day-to-day operations and maintenance of Landsat 5 and 7 to USGS.

The fact that a continuous uninterrupted record of land images dating back to 1972 exists is more a matter of good luck and excellent engineering rather than careful management oversight—see **Figure 3**. The premiere example of this good fortune is Landsat 5, launched in March 1984 and still operational in 2006, nearly two decades beyond its original three-year design life—truly amazing and very fortunate, given the failure of Landsat 6 and technical problems with Landsat 7.

#### Where the Landsat Program Stands Today: Landsat 7

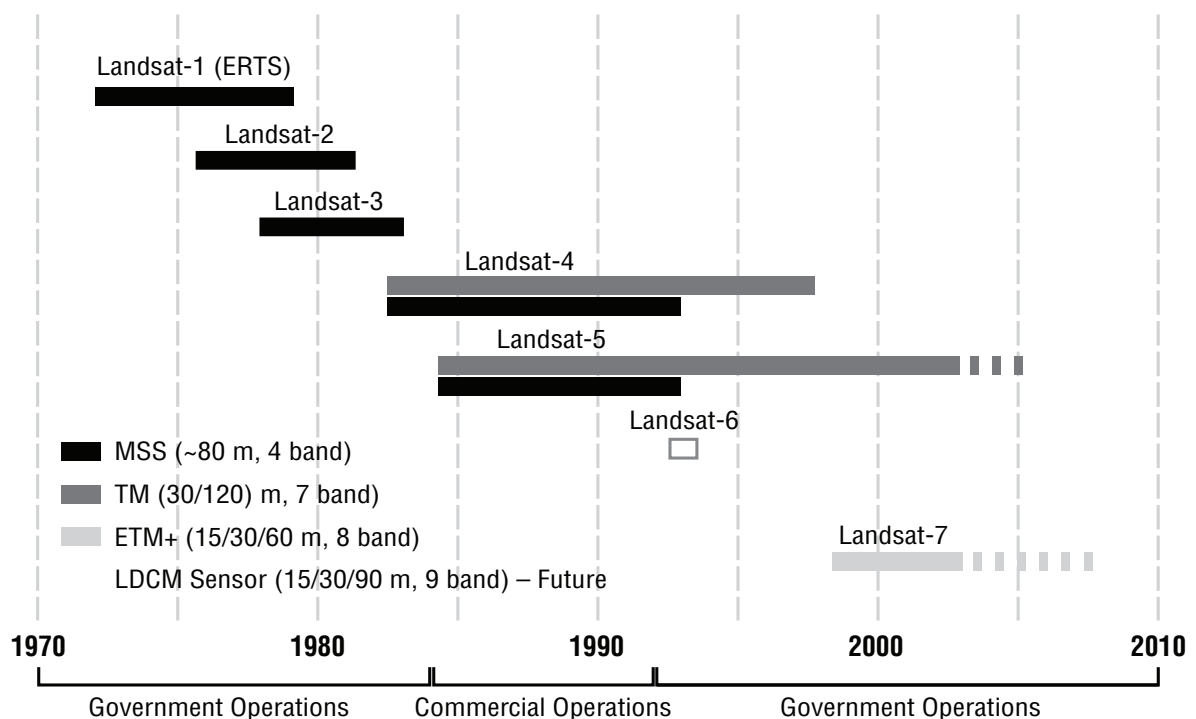
Launched on April 15, 1999, Landsat 7 is the latest chapter in the fulfillment of Pecora's dream of studying the dynamics of our home planet from space and carries on the mission of continuous monitoring and discovery of our terrestrial home at the human scale.

The database of Earth observation imagery resulting from Landsat 7 and its predecessors is unmatched in quality, detail, coverage, and value.

Landsat 7 improves on the technological foundation built by the previous Landsat missions. The Enhanced Thematic Mapper Plus (ETM+) instrument that flies on Landsat 7 builds on the capabilities of previous Landsat sensors—see **Table 2**. The average number of Landsat 7 scenes collected and downlinked to the U.S. archive each day has increased dramatically over previous missions—from ~50 to 250. To go along with this five-fold increase in the number of scenes acquired and archived, researchers have developed an automated cloud cover assessment (ACCA) capability, and a long-term acquisition plan (LTAP) to try and achieve a global, seasonally refreshed, cloud-free database from a single satellite. They've also developed an image assessment system (IAS) to run a series of quality checks on a sub-sample of the imagery received each day to ensure that data going into the archive is of the highest quality.

In late May 2003, the scan-line corrector (SLC) within the Landsat 7 ETM+ failed. Fortunately, the SLC failure did not impact the sensor adversely, but it did result in wedge-like data gaps on the left and right edges of every image—representing a ~25% loss of data from each scene. Scientists have come up with some “fixes” for this problem (i.e., various ways to “fill the gaps”) that are applied during the product generation phase. They have also changed the LTAP and Mission Scheduling software to modify the acquisition strategy so that

FIGURE 3: Landsat has had more than 34 years of continuous coverage.



Article Title [page numbers]	Author(s)	Summary of Content
<i>Requirements for a Landsat Data Continuity Mission</i> [pp. 1102 – 1108]	Irons & Masek	Gives details on the planned LDCM mission and procurement.
<i>Landsat: Yesterday, Today, and Tomorrow</i> [pp. 1171 – 1178]	Williams, Arvidson & Goward	Fits Landsat 7 in context of overall Landsat program, and shows how mission ops have evolved with time.
<i>In My Opinion: The Future of U.S. Land Imaging</i> [p. 1109]	Goward, Green, Lenczowski & Williams	Presents opinions on the future of U.S. land imaging— <i>op-ed</i> piece.
<i>Historical Record of Landsat Global Coverage: Mission Operations, NSLRSDA, and International Cooperator Stations</i> [pp. 1155 – 1169]	Goward, Arvidson, Williams, Faundeen, Irons & Franks	Provides comprehensive review of U.S. Landsat archive holding, revealing data gaps of varying magnitude.
<i>Landsat 7 Long-Term Acquisition Plan: Development and Validation</i> [pp. 1137 – 1146]	Arvidson, Goward, Gasch, & Williams	Reviews validation of the LTAP system for Landsat 7.
<i>Characterization of the Landsat ETM+ Automated Cloud Cover Assessment (ACCA) Algorithm</i> [pp. 1179 – 1188]	Irish, Barker, Goward & Arvidson	Discusses the approach used for the ACCA algorithm for assessing cloud cover in Landsat 7 imagery.
<i>Landsat 7 Long-Term Acquisition Plan Radiometry—Evolution Over Time</i> [pp. 1129 – 1135]	Markham, Goward, Arvidson, Barsi & Scaramuzza	Addresses the history, rationale, and results for various strategies that were used to set radiometric gains as part of the Landsat 7 LTAP.
<i>Landsat in Context: The Land Remote Sensing Business Model</i> [pp. 1147 – 1153]	Green	Provides perspective on how the management history of the mission conflicted with development of mission technologies.

TABLE 1: Summary of the articles in the Landsat Focus Issue of PE&RS, October 2006.

two relatively cloud-free images of the same location are acquired as soon as possible during subsequent overpasses. By acquiring two cloud-free images very close together, scientists can assure that the image they use to fill in gaps represents the same scene at the same approximate point in the growing season. (Prior to the SLC failure, once a cloud free image was acquired, they did not attempt to acquire another cloud free scene of the same area until the next “season”). The data from these image pairs can be used to generate a product where the gaps in one image are “filled” or merged from the other image in the pair.

As discussed earlier, in addition to Landsat 7, Landsat 5 is still operational today, 22 years after launch! This remarkable achievement gives scientists the luxury of having two operational land imaging satellites in orbit at the same time. The orbit cycles of the two satellites have been phased so as to yield eight-day repeat coverage anywhere on the globe, but with the caveat that Landsat 5 data can only be captured within line

of sight of those locations where operational ground stations are being maintained. (Landsat 5 never had an on-board recorder, and its Tracking and Data Relay Satellite (TDRS) links are no longer operational.)

### The Politics of Landsat, Part 2: Toward an Uncertain Future—LDCM and Beyond

The failure of the SLC on Landsat 7’s ETM+ has caused a great deal of concern in the Landsat user community about maintaining the continuity of global data collection with a Landsat-like sensor. The question quickly arose: *When might the next Landsat mission be ready for launch?* A simple enough question it would seem, but true to the tumultuous political history of the Landsat program to date, the answer to the question has been complex and convoluted. The law that turned control of Landsat back over to the Federal government in 1992, also called for the timely development of a follow-on system to maintain continuity beyond Landsat 7. But the law also required that four

different options for such a follow-on system must be “fully” investigated, namely:

1. private/commercial solution;
2. joint governmental/commercial venture;
3. international consortium solution; and
4. Federal Government solution—such as that implemented for Landsat 7.

The wording of the law made it very clear that option 4 above—a wholly Federal Government solution—was *not* preferred.

Planning for a follow-on mission began long before Landsat 7 was launched, but it was not until 2001 that NASA and USGS officially initiated the Landsat Data Continuity Mission (LDCM) to meet the goal of the law. Following initial attempts to explore a procurement of commercial imagery, and then discussions about integrating a Landsat-class sensor aboard the National Polar-orbiting Operational Environmental Satellite System (NPOESS) platform, current plans call for a government managed “free flyer.” As of today the projected launch date for LDCM is no earlier than 2011, and given the age and condition of Landsats 5 and 7, it appears highly likely that there will be a *data gap* before LDCM becomes operational. To avoid a repetition of this situation in the future, the White House Office of Science and Technology Policy (OSTP) has recently convened a working group to address Landsat continuity and the future of land imaging. Known as the Future of Land Imaging or FLI working group, their report to Congress and the President is expected by next spring. Jim Irons and Jeff Masek have contributed a paper to the special issue of *PE&RS* that goes into more detail about the plans for LDCM—see **Table 1**.

**TABLE 2:** Evolution of the Landsat sensor suite.

Sensor	Spacecraft(s) Flown On	Enhancements Over Previous Sensor
Multispectral Scanner	Landsats 1-3	<ul style="list-style-type: none"> <li>• Four spectral bands (Green, red, and two near-infrared)</li> <li>• 80-m resolution</li> <li>• Multispectral scanner vs. camera</li> </ul>
Thematic Mapper (TM)	Landsats 4&5	<ul style="list-style-type: none"> <li>• Two additional bands in shortwave SR and one in thermal IR</li> <li>• 30-m resolution</li> </ul>
Enhanced Thematic Mapper (ETM)	Landsat 6*	<ul style="list-style-type: none"> <li>• 15-m panchromatic band added for edge sharpening</li> <li>• Selectable high/low gain for each spectral band.</li> </ul>
Enhanced Thematic Mapper Plus (ETM+)	Landsat 7	<ul style="list-style-type: none"> <li>• 60-m thermal IR vs. 120-m</li> <li>• Onboard partial aperture and full aperture calibrators.</li> </ul>

\* Landsat 6 failed to reach orbit so ETM never operated on orbit; NASA had *no* involvement with the development or launch of Landsat 6.

## Conclusion

Landsat began as an experiment, but it is now a fundamental part of the nation’s infrastructure. The Landsat program has become a central pillar of the national remote sensing capability. Landsat established the U.S. as the world leader in terrestrial remote sensing, contributed significantly to the understanding of the Earth’s environment, spawned revolutionary uses of space-based data by the commercial value-added industry, and encouraged a new generation of commercial satellites that provide regional, high-resolution spatial images. The archive of historical Landsat data is a national treasure of immeasurable value, and the responsibility for the creation and maintenance of that archive resides at the USGS National Center for Earth Resources Observation and Science (USGS/EROS).

The Landsat series of satellites has been providing digital image data of the Earth for more than 34 years—see **Figure 3**—and the data is among the most valuable assets available to the Earth science user community. Landsat observations have become invaluable in helping scientists understand changes in the land surface, cope with the challenges of nature, and exploit the resources of the Earth. Landsat data have done as much to solidify the concept of Earth systems science over the past two decades as any other single source of terrestrial information. These data provide consistent, reliable documentation of global land-cover type and land-cover change over the past three decades. The work presented in the *PE&RS* Focus Issue on Landsat provides an update on efforts to maintain and increase the quality of the Landsat observation record through the Landsat 7 mission—see **Table 1**. Hopefully, lessons learned in this decade will continue to influence land remote sensing scientists and engineers in the decades to come. ■



## The GLIMS Glacier Inventory of the Antarctic Peninsula

Frank Rau, *Institut für Physische Geographie, Universität Freiburg*, [frank.rau@geographie.uni-freiburg.de](mailto:frank.rau@geographie.uni-freiburg.de)

Jeffrey S. Kargel, *University of Arizona*, [kargel1054@earthlink.net](mailto:kargel1054@earthlink.net)

Bruce H. Raup, *National Snow and Ice Data Center, University of Colorado*, [braup@nsidc.org](mailto:braup@nsidc.org)

At the start of the new millennium, the climate in many parts of the polar regions is changing rapidly, and the influence of human-produced emissions of greenhouse gases is believed to be a major contributing factor. With temperature rises unequalled in the history of climatic observations, global climate of the 20<sup>th</sup> Century changed at an average rate beyond combined uncertainties and at a magnitude unprecedented in the last millennium. Although there is general agreement on the evidence of global warming, there is still much debate on the magnitude and the regional pattern of these changes and of the response of cryospheric systems to climate change.

A dramatic example of extraordinarily strong regional warming is observed around the Antarctic Peninsula. Even taking into consideration the extremely large inter-annual variabilities that characterize the meteorological records for this region, the warming rates identified on the western coast of the Antarctic Peninsula are greater than those found elsewhere in Antarctica. Furthermore, analysis of synoptic observation records and proxy values reveals that precipitation patterns on the Antarctic Peninsula are changing. These changes in temperature and precipitation in recent years directly result in fluctuations in the annual mass and energy balance cycles of the glacial systems of the Antarctic Peninsula. The consequences include the spectacular disintegration of ice shelves on both sides of the peninsula, acceleration of glaciers feeding those ice shelves, marked changes in the glacier frontal positions, and the retreat of grounding line positions of the floating ice tongues. Observational evidence suggests that there is much more spatial and temporal variability in the grounded and floating parts of local glacial systems than previously expected. Because of the extraordinary rate of warming on the Antarctic Peninsula and related changes in glaciers, the Intergovernmental Panel on Climate Change (IPCC) chose this region as one of eight key polar regions for detailed investigation.

The northern Antarctic Peninsula is dominated by an alpine glacial system consisting of an ice cap covering the central plateau region, which feeds numerous outlet glaciers draining to both sides of the peninsula. The majority of these flow into ice shelves or terminate as tidewater glaciers. In addition, isolated ice caps, mountain glaciers, and ice piedmonts characterize the margins of the peninsula and the adjacent islands. In contrast to the slow reaction of continental ice masses, the relatively small glaciers on the Antarctic Peninsula react with short response times (time scale: years to decades) to perturbations of their accumulation and ablation processes. These glaciers are therefore recognized to be superior in-

dicators of the spatio-temporal variability of the regional climate system.

As part of the multi-national Global Land Ice Measurements from Space (GLIMS) project, the Department of Physical Geography of the University of Freiburg (Germany) monitors the glaciers of the Antarctic Peninsula. GLIMS was established to acquire satellite multi-spectral images of the world's glaciers and analyze them for glacier extent and changes, and to understand these change data in terms of climatic and other forcings—[www.glims.org](http://www.glims.org)—GLIMS makes use of state-of-the-art imaging and image-analysis technology, and is designed to monitor the world's glaciers primarily using data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard the EOS Terra spacecraft. Complementary image data from additional sensors such as Landsat, European Remote-sensing Satellite-1/2 (ERS-1/2), and CORONA, as well as information obtained from historic maps and air photographs are integrated into the general workflow. The project as a whole was originated and has been coordinated by the U.S. Geological Survey in Flagstaff, Arizona, but is now coordinated from the University of Arizona in Tucson, Arizona. GLIMS provides a global network for glaciologists from more than 60 scientific institutions across the globe.

The GLIMS consortium is organized into a system of Regional Centers (RCs), each of which is responsible for glaciers in their region of expertise. The standardized results of the glacier analyses are archived together with the corresponding meta-information in the GLIMS Glacier Database, which was designed and implemented at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado—[nsidc.org/glims/](http://nsidc.org/glims/).

One of the main tasks of the RC of the Antarctic Peninsula hosted at the Department of Physical Geography of the University of Freiburg is the compilation of a glacier baseline inventory for the Antarctic Peninsula and the derivation of morphometric glacial parameters, which will facilitate a consistent glacier monitoring and geo-statistical analyses on the peninsula in the future. In its current version, the glacier inventory comprises more than 1100 entries of all glacial systems and individual glaciers from the Antarctic Peninsula north of 70° S and the adjacent islands.

The first step in compiling the glacier inventory is the identification of the individual glaciers. Because the Antarctic Peninsula is almost entirely covered in ice, and is quite complex glaciologically, a complete identification of absolutely all ice masses down to the smallest ice fringes,

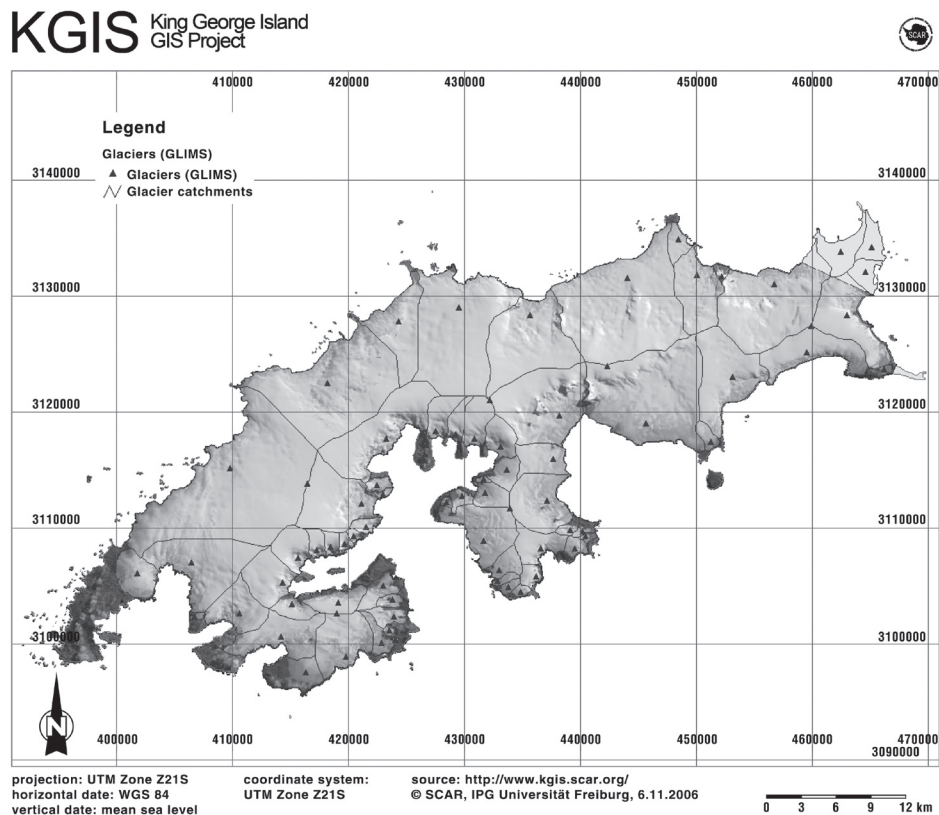
glacierets and snowfields is not possible. Consequently, all those glaciers definable from satellite images that meet at least one of the following criteria are defined as individual ice masses:

- Glaciers named on published maps or listed in the current version of the *Composite Gazetteer of Antarctica*—CGA; [www3.pnra.it/SCAR\\_GAZE](http://www3.pnra.it/SCAR_GAZE).
- Unnamed valley glaciers or outlet glaciers terminating as tidewater or terrestrial glaciers or draining into an ice shelf.
- Unnamed glaciers unrestricted by topography exceeding a minimum size—e.g. small island or mountain ice caps.
- Ice masses which are part of superior glacial systems and which are identifiable by an individual velocity field.
- Small glaciers of historic or scientific importance.

Most glaciers on the Antarctic Peninsula do not have official and internationally accepted names. The multinational history of scientific exploration and surveying on the Antarctic Peninsula, territorial claims, and the absence of a responsible naming authority under the Antarctic Treaty System, have resulted in numerous

cases of multiple names for single features, and inconsistent practices in the recognition and use of existing names. To avoid further confusion and inconsistencies, and to bring some order to the local toponymy, the Scientific Committee on Antarctic Research (SCAR) promotes adoption of the general naming convention of *one name per feature* for all Antarctic geographic names. Therefore, all existing object names are checked in reference to the *Composite Gazetteer of Antarctica* and published maps. For objects with multiple names, a single name is fixed following the principle of historic priority. To provide highest compatibility with the *Composite Gazetteer of Antarctica*, maps and other publications, the synonyms are stored in addition to the approved object names in a supplemental data field together with a three-letter International Organization for Standardization (ISO) country code indicating the original source of each name.

Because each glacier record can point to a *parent ice mass* in the GLIMS Glacier Database, the representation of complex glacial systems with interconnections and relationships between different ice masses (e.g. an outlet glacier draining an ice cap) can be accomplished. The relation of each glacier to up- or downstream connecting ice masses is checked during the



**The glacier inventory of the King George Island ice cap.** King George Island is the largest of the South Shetland Islands located northwest of the Antarctic Peninsula. The island is home to about 80 glaciers, which are characterized in terms of their catchment boundaries and represented by an individual ID point (black triangles) located within the glacier polygon. Multi-spectral image classification techniques, morphometric analysis of digital terrain models, and personal experience from previous field campaigns were used to determine the surface area of the glaciers. Additional time-invariant and dynamic information on each glacier are stored in the geospatial relational GLIMS Glacier Database. The inventory presented is extracted from the *SCAR King George Island GIS Project* (KGIS, [www.kgis.scar.org/](http://www.kgis.scar.org/)). The image background is an ortho-rectified Système Pour l'Observation de la Terre (SPOT) image from February 2000.

glacier identification process. Ice masses such as ice caps, plateau glaciers, or ice fields were flagged as parent ice masses, while the ID of the appropriate parent ice mass was assigned to the individual subordinated glacial components—e.g. outlet glaciers, ice shelves.

Researchers use satellite imagery and supporting data from other sources—e.g. ground-based measurements—to extract information about the static and dynamic parameters of each glacier, and categorize each glacier using the modified GLIMS glacier classification scheme. In addition, the researchers use satellite imagery and Digital Elevation Model (DEM) output to develop datasets that contain information on the catchment and glacier boundaries. These datasets also include derived parameters, such as surface areas, length, and width, as well as additional information such as frontal position lines, center-lines, and snowline positions. All of this data is exported to the GLIMS-specific database ingest format.

Analysis of high resolution ASTER data co-registered to Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data provide information on glacier front variations between the years 1986 and 2002. In regional case studies, more than 300 glaciers were examined, covering a variety of glacial systems distributed over the northern Antarctic Peninsula. Of these, only 40 (12.8%) displayed advancing glacier fronts accounting for a gain of 7.1 km<sup>2</sup>, while 171 (54.6%) showed retreating ice fronts accounting for a loss of 146.1 km<sup>2</sup>. In addition, 102 (32.6%) were found to be in invariant conditions. The glaciers examined displayed no indications of dynamic flow instabilities. The observed glacial variations are therefore interpreted as direct consequences of the rapidly changing climatic conditions in the region that are affecting accumulation and ablation.

Beyond the overall trend toward retreating ice fronts, observations dating from the mid 1980s to 2001 reveal different patterns of glacier variation across the Antarctic Peninsula. An area of significant retreat is concentrated on the northeastern sectors of the peninsula—eastern coast of Trinity Peninsula and James Ross Island. Similarly, a consistent distribution of predominant glacial recession is also identifiable along the southwestern coasts of the study area—Graham Coast, Loubet Coast and Marguerite Bay. This is in sharp contrast with glacier frontal positions recorded in northwestern parts of the Antarctic Peninsula adjacent to Bellingshausen Sea, where only slight recessions and minor advances were recorded—western coast of Trinity Peninsula and Danco Coast. These observations from the northwest, which are presumed to be in the natural range of frontal fluctuations of tidewater glaciers, suggest relative dynamic stability of the glacial systems in this sector.

With long-term observations lacking from most parts of the Antarctic Peninsula, the high data availability on James Ross Island offers the possibility for a continuation of previous glacier monitoring activities. Analyzing the glacial variations on a larger perspective, a drastic acceleration of glacier recession could be determined on the island since 1988. In comparison to a retreat rate of 1.84 km<sup>2</sup>/a from 1975 to 1988 (Skvarca and others, 1995), the annual reduction of glaciated areas doubled to 3.79 km<sup>2</sup>/a from 1988 to 2001. Moreover, contrary to the situation in 1988, the majority of glaciers terminating on land in 2001 are now retreating. Over the entire period between 1975 and 2002, the glaciers on James Ross Island are found to have decreased by 78.8 km<sup>2</sup> corresponding to 3.9% of the previously ice-covered area.

These observations provide more evidence of the significant impacts of recent rapid climate change on the cryospheric environment of the Antarctic Peninsula. Furthermore, they highlight the importance of a consistent glacier monitoring in this region by means of high-resolution satellite image data. Innovative spaceborne sensors such as ASTER and new data acquisition and distribution strategies have led to a better coverage of the polar regions with satellite data in space and time, thus providing the required tools to accomplish the aim of establishing a functional monitoring program and to contribute the ongoing research efforts in the field of climate change.

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## Arctic Sea Ice Shrinks as Temperatures Rise

Stephanie Renfrow, NSIDC, [srenfrow@nsidc.org](mailto:srenfrow@nsidc.org)

Jim Scott, University of Colorado at Boulder, [Jim.Scott@colorado.edu](mailto:Jim.Scott@colorado.edu)

The year 2006 continues the pattern of sharply decreasing Arctic sea ice, raising further concern that the Arctic is responding to greenhouse warming. National Snow and Ice Data Center (NSIDC) Senior Research Scientist **Mark Serreze** said, “If fairly cool and stormy conditions hadn’t appeared in August slowing the rate of summer ice loss, I feel certain that 2006 would have surpassed last year’s record low for September sea ice.”

On September 14, the melting season came to a close. On this day, known as the *sea ice minimum*, sea ice covered 5.7 million km<sup>2</sup> (2.2 million mi<sup>2</sup>) of the Arctic, the fourth lowest of the 29-year satellite record for a single day. The average sea ice extent for the entire month of September was 5.9 million km<sup>2</sup> (2.3 million mi<sup>2</sup>), the second lowest on record, missing the 2005 record by 340,000 km<sup>2</sup> (131,000 mi<sup>2</sup>). Sea ice extent is the sum of all regions where ice covers at least 15% of the ocean surface.

**Figure 1** shows average ice extent for September 2006; the black line indicates average September conditions over the long-term record. In nearly all areas, sea ice retreated well

**Arctic Sea Ice Extent September 2006**



**Figure 1:** September 2006 sea ice extent. This white area shows the average sea ice extent for the month of September; the black line indicates the average September sea ice extent from 1979 to 2000. 2006 had the second-lowest average September sea ice extent on record. **Credit:** National Snow and Ice Data Center, Sea Ice Index.

north of where it should have been in a typical September, continuing the pattern of dwindling September sea ice.

Including 2006, the September rate of sea ice decline is now approximately  $-8.59\%$  per decade, or 60,421 km<sup>2</sup>/year (23,328 mi<sup>2</sup>/year. NSIDC Research Scientist **Julienne Stroeve** said, “At this rate, the Arctic Ocean will have no ice in September by the year 2060.” The loss of summer sea ice does not bode well for species like the polar bear, which depend on the ice for their livelihood, she said.

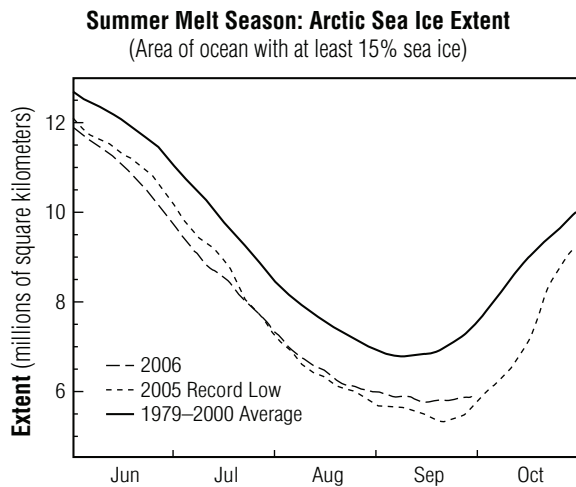
Ice extent from January through the middle of July 2006 was well below 2005 conditions, which, if it had continued, would have led to a new record low. **Figure 2** shows a timeline of sea ice extent from June through October; the long-dashed line that indicates 2006 trails beneath the short-dashed line of 2005 until mid-July.

The low sea ice through mid-July was consistent with the very warm air temperatures that scientists were also tracking in the Arctic. Serreze said, “High temperatures over the winter helped limit ice growth so that less ice formed. Much of the ice that did grow was probably thinner than normal. Unusually high temperatures through most of July then fostered rapid melt—a bad combination, as far as the sea ice was concerned.”

However, air temperatures dipped a bit lower in August. “August broke the Arctic heat wave and slowed the melt, and storm conditions led to wind patterns that tend to spread the existing ice over a larger area,” Serreze said. Then, in September, temperatures returned to the above-normal pattern. The warmer temperatures have meant a slow recovery from the September minimum—note how the curve is flattening during September in **Figure 2**. At this rate, sea ice may set a new record, this time for lowest October sea ice extent, Serreze said.

Another notable feature of the 2006 melt season was the development of a large *polynya*—an area of persistent open water surrounded by sea ice—north of Alaska; see **Figure 3**. Research scientist **Walt Meier** said that near its largest, in early September, the polynya was the size of the state of Indiana. How the polynya formed is still not clear. Unusual wind patterns may have forced the ice cover to spread apart. Scientists also speculate that thin ice moved into the area over the winter, melting out over the summer and creating the polynya. Another possibility is that warm waters rose to the surface, helping melt the ice.

The team felt it would be irresponsible to attribute the polynya to greenhouse warming. “However, as the ice



**Figure 2:** Time series plot—2006, shown in the long-dashed line, is below even the record year (2005), shown as a short-dashed line, until mid-July, when sea ice conditions improved because of cooler Arctic temperatures. However, 2006 was still well below the 1979 to 2000 average, shown in solid black. **Credit:** National Snow and Ice Data Center.

continues to thin with increasing climate warming, we may see features like this more often,” Meier said.

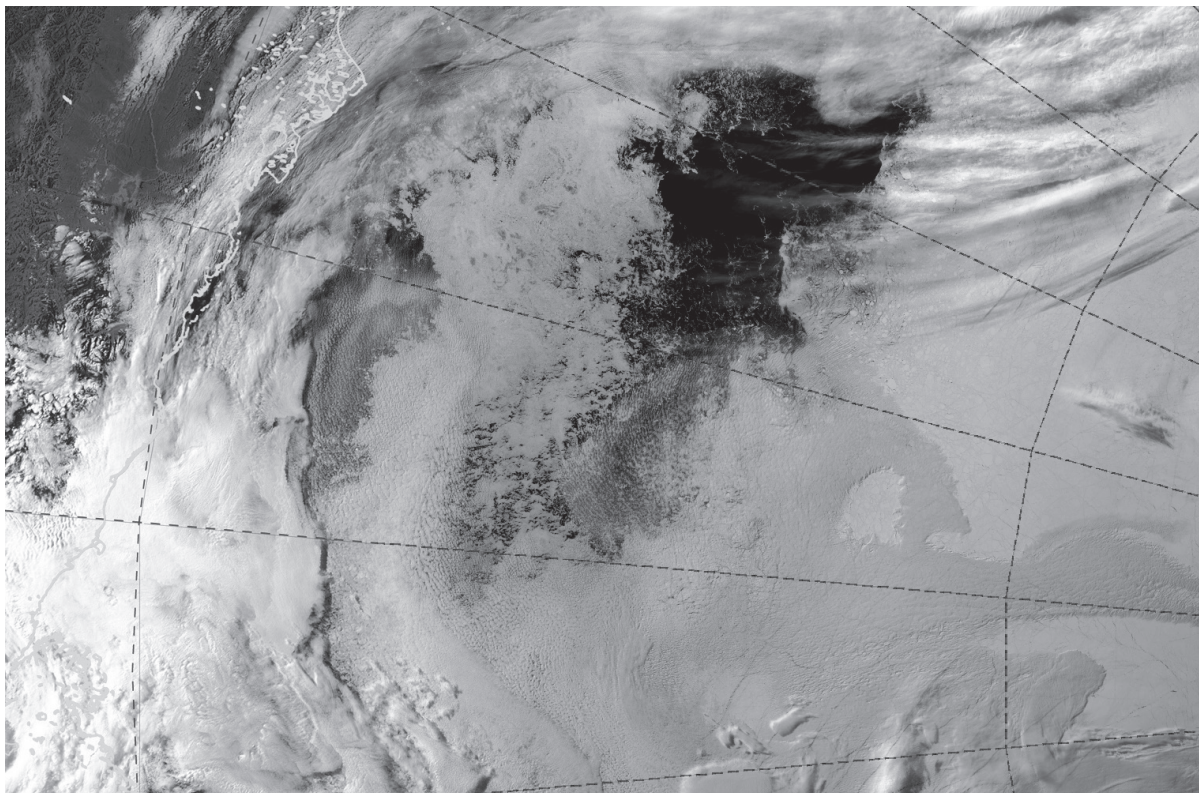
NSIDC Lead Scientist **Ted Scambos** added, “Arctic sea ice is an important climate indicator because it’s so sensitive to this initial warming trend.” As sea ice melts in response to rising temperatures, it creates a *positive feedback loop*: melting ice means more of the

dark ocean is exposed, allowing it to absorb more of the sun’s energy, further increasing air temperatures, ocean temperatures, and ice melt. The observed changes in the ice cover indicate that this feedback is now starting to take hold. Sea ice is only one indicator of Arctic change amongst many, such as warming of permafrost, changing patterns of vegetation from tundra to shrubs, a warming ocean, and accelerated melt of the Greenland ice sheet.

Given the especially steep decline of sea ice since 2002 and the record low in September 2005, scientists at NSIDC have been closely monitoring this year’s sea ice conditions, posting new images and commentary in online updates throughout the end of the melt season. NSIDC plans to continue to watch the sea ice and report on milestones in the coming year.

“I’m not terribly optimistic about the future of the ice,” Serreze said. “Although it would come as no surprise to see some recovery of the sea ice in the next few years—such fluctuations are part of natural variability—the long-term trend seems increasingly clear. As greenhouse gases continue to rise, the Arctic will continue to lose its ice. You can’t argue with the physics.”

To view the original press release from the National Snow and Ice Data Center (NSIDC) dated October 3, 2006, visit [nsidc.org/news](http://nsidc.org/news) ■



**Figure 3:** Beaufort Sea Polynya. An unusual *polynya*—an area of persistent open water surrounded by ice—appeared during the melt season. The polynya is the dark area of open water; to the left is the coastline of Alaska, and to the right is the North Pole. This image is from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, which flies on the NASA Terra and Aqua satellites. **Credit:** National Snow and Ice Data Center.

## Excellence in Outreach Workshop

David D. Herring, Goddard Space Flight Center, David.D.Herring@nasa.gov

On June 15-16, 2006, NASA's Earth Sciences Division (ESD) sponsored a two-day "Excellence in Outreach Workshop" at the Maritime Institute in Linthicum, MD. The purpose of this workshop was to conduct a qualitative review of the NASA Earth Sciences Division's (ESD) Outreach Program. The design of the workshop was experimental. The objective was to solicit feedback from two teams of senior communications professionals: one that knew a great deal about NASA's ESD and how the agency goes about communicating that knowledge to the public (i.e., the "well-informed" team), and one that knew virtually nothing about NASA's ESD at the outset (i.e., the "less-informed" team). The workshop agenda, copies of all the panelists' presentations, and a more detailed summary of the workshop are available at [esdepo.gsfc.nasa.gov/calendar/cal-files/20060615-16.html](http://esdepo.gsfc.nasa.gov/calendar/cal-files/20060615-16.html).

### Who Were the Panelists?

Eight distinguished science communications professionals were selected to participate in the workshop. A brief bio of each panelist, listed in alphabetical order, is presented below.

**Rick Borchelt** is an award-winning science writer who currently serves as the Communications Director for the Genetics and Public Policy Center at The Johns Hopkins University. He has had a distinguished career in science communications and science public policy, including serving as Media Relations Director for the National Academy of Sciences; Press Secretary for the U.S. House of Representatives Committee on Science, Space and Technology under the chairmanship of the late Rep. George E. Brown, Jr.; Special Assistant for Public Affairs in the Executive Office of The President during the Clinton Administration; Director of Communications for the Department of Energy's Office of Science; and Director of Communications and Public Affairs at The Whitehead Institute for Biomedical Research at MIT. He also serves as reports editor for the peer-reviewed journal *Science Communication*.

**Jon Franklin** is a two-time Pulitzer Prize-winning journalist (for feature writing in 1979 and expository journalism in 1985) and a pioneer in literary nonfiction writing. He is an expert in unraveling complex scientific advancements for the masses as Franklin's work frequently focuses on the human side of science and technology. In a career that has spanned more than four decades he has written five books and a variety of magazine articles, newspaper stories and series. He has taught at the University of Maryland, Oregon State University, and the University of Oregon, where his duties included

the directorship of the creative writing program. He also has written four books on science topics, including *Writing for Story*, which is widely used in advanced journalism classes around the world.

**Kendall Haven** has the distinction of being the only West Point graduate to ever become a professional storyteller. Haven holds a Doctorate in Oceanography and spent ten years as a Senior Research Scientist for the Department of Energy before finding his true passion for storytelling. Haven has performed for more than four million people in 42 U.S. states and four foreign countries, and he has won numerous awards both for his story writing and for his storytelling.

**Susanna Priest** is Associate Professor and Director of Research in the College of Mass Communications and Information Studies at the University of South Carolina, in Columbia. She had previously directed the graduate program in science journalism at Texas A&M University and the Center for Science and Technology Policy and Ethics, also at Texas A&M. Priest has published more than 40 book chapters and articles, primarily on the media's role in communication of science, risk, and uncertainty. Her recent projects have considered risk communication in contexts ranging from Hurricane Katrina evacuation to public understanding of nanotechnology to terrorism threats and collective behavior. She has recently finished serving on a National Academy Engineering committee on assessing technological literacy, and continues her membership on NASA's Planetary Protection Advisory Committee.

**Thomas Lucas** is a producer and director who has created award-winning films on science and natural history topics for over a decade. He recently completed his third special for Dynamic Data Exchange (DDE) and Public Broadcasting Service (PBS) titled *Beyond Human*, a fascinating two-hour look at the growing merger of man and machine. Lucas has produced three films for PBS' *NOVA* series, and several *World of Audubon* specials for Turner Broadcasting. His work has also appeared on The Discovery Channel and he is currently working on an HDTV production for the network. Lucas received an M.F.A. in Film from Columbia University in 1977.

**Terrence McNally** is a speaker, consultant, writer, and coach for foundations, corporations, public agencies, and non-profit organizations. His work focuses on the mastery of message and media and the power of storytelling. A graduate of Harvard, where he won its highest academic award, McNally hosts interview programs on radio and television.

**Jon D. Miller** is a professor in the Medill School of Journalism and Director of the Center for Biomedical Communications at Northwestern University in Chicago. Trained as a political scientist, Miller brings the social science skills of survey research and quantitative analysis to the study of the public understanding of science and technology. For two decades, he has designed and conducted the biennial national studies of the public understanding of science and technology for the National Science Board, published biennially as *Science and Engineering Indicators*. His work in the measurement of scientific literacy and attitudes has been replicated in more than 20 countries. Miller also serves as Director of the Longitudinal Study of American Youth (LSAY) and as Director of the International Center for the Advancement of Scientific Literacy, both located at Northwestern University. He has published five books and more than 40 articles and chapters in the area of the public understanding of science and technology and in the development of science and mathematics skills during secondary schooling and college.

**Gail Porter** has been a science writer and editor, communications manager, and public information officer for the last 28 years. She currently serves as Chief of the Communications and Inquiries Group for the National Institute of Standards and Technology, where she is responsible for central coordination of NIST's external and internal Web sites, publications, exhibits, speeches, and other communications products. In her spare time Porter moonlights as President of the D.C. Science Writers Association, a group of writers that hosts monthly lectures and other types of events for journalists and press information officers in the D.C. metropolitan area. From 1981-90, Porter handled media relations for the National Academies of Sciences and Engineering, including five years as Director of the Office of News and Public Information.

### How Was the Experiment Set Up?

The eight panelists were divided into two teams. One team was designated as the “less-informed” team because they knew virtually nothing about NASA's ESD at the outset. The other group was designated as the “well-informed” team, because they already knew a great deal about NASA's ESD and how the agency goes about communicating to the public. Care was taken to ensure there was good symmetry between both teams in terms of the panelists' expertise and backgrounds. Each team contained a representative of the general public, informal educators, public media, and policy makers and stakeholders. **Table 1** shows a breakdown of the two teams.

Four weeks prior to the workshop, **David Herring** [NASA Goddard Space Flight Center—*Acting ESD Outreach Program Manager*] briefed both teams of panelists about the terms and conditions of this experiment, and the parameters of their assignment. Great care was taken to present just enough information to whet the appetite of the “less-informed” team but not to bias them in terms of their information seeking. Conversely, the “well-informed” team received a very detailed presentation about NASA's ESD and the public outreach strategies it currently employs. Each panelist was paid an honorarium of \$500 per day (for 5 total days) plus travel expenses to participate in this experiment, except Gail Porter, who could not accept an honorarium because she works for NIST and, therefore, donated her time and expertise *gratis*. The total cost of the workshop was about \$35K.

### What Were the Panelists Asked to Do?

The panelists' assignment was to spend no more than the equivalent of 3 workdays (24 hours) seeking information about NASA's ESD—whatever they could find, wherever they could think to look, or from whomever they could

TABLE 1: Breakdown of Panelists.

Group Represented	Representative from the Less-Informed Team	Representative from Well-Informed Team
The General Public	Jon Franklin	Rick Borchelt
Informal Educators	Terrence McNally	Kendall Haven
Public Media	Gail Porter	Thomas Lucas
Policy Leaders and Public Stakeholders	Susanna Priest	Jon Miller

find to ask. They were asked to pay particular attention to whatever information sources they would imagine their assigned target audiences would be likely to seek. Then they were asked to answer the following questions for presentation on the first day of the workshop:

- *Where did you look and what did you find?*
- *What did you learn about NASA's ESD from what you found?*
- *What attitudes or opinions did you form about NASA's ESD?*
- *What did you not find that you thought you would, or should?*
- *Based upon all of the above, what recommendations to NASA would you make?*

#### **What Did the Panelists Conclude?**

As one might imagine, some of the information that came out during the course of the workshop was good and some of it was not so good. Unanimously, our distinguished panelists were enthusiastic about NASA Earth Science. Moreover, the panelists all agreed that we have compelling messages and stories that the American public wants to know about. In general, the quality of the textual and visual information available from NASA's ESD was deemed "good" or "excellent" but, ironically, much of it is hard to find and harder to use. This problem seems to stem from the fact that there are many messages going out from NASA's ESD about our missions and research, and also many messages going out about NASA more generally. Our panelists felt this "plurality of voices" coming from the agency makes it hard for people outside the agency to ascertain what our main messages and resources are and where to go to find them. In short, they said, NASA's ESD suffers from both an *accessibility problem* and a *branding problem*. Our agency's organization is too large and the scope of our Earth Science research is too complex to effectively communicate it all to the lay public through "many small, disconnected, dispersed packets of information." Our attempts to do so thus far have been, effectively, "cacophony" or "white noise" (to use two different participants' terms) from the public's perspective. We need more broadly integrative information resources to help our audiences put our ESD missions and research programs into proper perspective. Further, specialized stakeholder audiences such as the scientific community and policy leaders in government have very different needs from those of the "general" lay public, and a single set of messages or vehicles may not effectively serve all of these needs.

Our panelists recommended strongly that the ESD should stake out its own intellectual territory in a way

that concisely conveys our uniqueness and relevance. They zoomed in on NASA's planetary perspective as something unique and which establishes NASA's ESD as a world leader. However, they cautioned that different audiences look for different types of information in different ways, and with different motivations for looking. Some people want actual data or the conclusions from them; some want evidence of a per-dollar impact of our programs and missions; some want pretty pictures; and some want an entertaining and informative narrative of how our scientists reached a new milestone or scientific discovery. There was debate as to whether the best way to serve this diversity of audiences was through the use of multiple Web portal products, or through one very well-integrated portal with clearly defined sections for our various audiences. Either way, everyone agreed that we should spend more time and effort to better define our audiences and to better characterize what they want and how they look for it. Moreover, it was recommended that we work harder, and through our scientists, to cultivate better relationships with scientific professional societies. Such societies can serve as advocates for our work and as "validators" for our results likely better than NASA's ESD can.

Perhaps most noteworthy, our panelists voiced surprise and concern over the fact that NASA's ESD lacks mechanisms to test the effectiveness of our programs and products. One panelist wrote, "Active feedback is essential to successful outreach." Another panelist suggested funding further research into who our priority audiences are and what *they* feel are their needs, wants, and expectations for Earth Science information. We could then "reverse engineer" our efforts to ensure they are well matched to our target audiences' needs and ways of looking. And, more to the point, we could begin with a baseline of what our audiences know and think about NASA's ESD, and then we could measure how their knowledge and perceptions change over time. This is precisely the feedback our panelists and participants felt is needed to guide the evolution of the ESD's outreach programs and products into the future.

#### **What is the Collective Wisdom of the Workshop Participants on Outreach?**

NASA ESD Outreach personnel from across the agency attended the first day of the meeting as each panelist from both groups gave their reports. Then, on day two, a series of facilitated roundtable discussions involving all attendees took place. Participants divided into three discussion groups as a function of audience—i.e., the public and informal educators, public media, and policy makers and stakeholders. Our panelists were given audience assignments; NASA personnel were free to self-select which group to join.

The point of these discussions was to ascertain the "col-



lective wisdom” in answering basic questions about how NASA’s ESD should go about communicating with its particular target audiences. The idea was to use lessons learned and information discussed on Day 1 of the workshop to help guide and frame discussions during Day 2. Moreover, the questions were designed in hopes that one discussion session would lead logically into the next so that there would be a gradual building toward a collective, cohesive vision by the end of the day. The reader is once again referred to [esdep.gsfc.nasa.gov](http://esdep.gsfc.nasa.gov) for complete summaries of these group discussions.

Recalling the panelists’ presentation and plenary discussions from the first day of the Workshop, in the first breakout session, all three groups were asked to discuss and answer the following questions:

- What do you feel are the NASA ESD Outreach Community’s strengths?
- What are its weaknesses?
- How can we preserve and extend from our strengths while shoring up our weaknesses?

In the second group breakout session, participants discussed the following questions:

- What should be our main communications goals and objectives for each audience (recognizing that they may vary)?
- What are realistic outcomes of a well-designed communications strategy aimed at each target audience?
- How should we go about building healthy relationships with each audience?
- What characteristics define a healthy relationship with each audience?

There was consensus among participants that NASA’s ESD should refine its overall public outreach effort as a function of target audience. Specifically, NASA should begin by clearly defining its audiences and then better adapting its outreach programs and products in ways that are in accordance with each audience’s needs and expectations. To do this, attendees recommended putting into place feedback loops that help us quantify and assess the effectiveness of our communications efforts over time.

There are several constraints that exist today in NASA that currently seem to interfere with the ESD’s ability to refine its outreach efforts. The first constraint is the agency organization chart—ours is a highly fragmented community with precious little cohesion and synergy.

The second constraint is the mechanism by which the agency disburses funds for education and outreach—mainly through competed solicitations. This enhances the fragmented nature of our outreach community and discourages cooperation in any long-term, overarching vision for public communication. The third of these constraints is a lack of dialogue between the agency’s senior managers and internal decision-makers and the rest of the NASA community—including scientists, mission managers, education and outreach personnel, etc. Thus, there is little agreement among NASA personnel in terms of our target audience priorities, what are the best methods and media through which to communicate with them, what are our main messages for each audience, and what are communication objectives for each audience. Buy-in is clearly needed from senior management if we are to succeed in refining our outreach effort.

Specifically, the following recommendations were made:

- Provide “financially encouraged” collaboration among internal outreach personnel. The issue isn’t seen as a lack of funding; rather, there needs to be a change in how the funding flows so as to foster greater cooperation.
- Build into our outreach budget the time and funds needed to devise ways of making our outreach products more extensible and/or ways of adding value to them, thus improving overall efficiency.
- Develop and rally behind a bold branding message that clearly identifies NASA as “the planetary agency with the planetary vision.” One panelist stated: “You carry the public trust in pioneering space-based technology and planetary science.” Is this role clear to our stakeholders and publics?
- Develop and implement feedback loops for each priority audience to quantify and assess our effectiveness over time.

In conclusion, the Workshop was a success, both in terms of its experimental nature and in terms of the overwhelmingly positive feedback from panelists and participants alike. Our next steps will be to consolidate the lists of issues, challenges, opportunities, and recommendations and then to schedule the follow-up town hall meeting with senior management to work toward finding solutions. While the ESD could easily point to successful outreach efforts and argue that the “glass is more than half full,” the counterpoint is that until we more clearly define our audiences and objectives, and then put into place good feedback mechanisms, NASA’s ESD will always lack the data it needs to quantify and assess its public communications effectiveness. ■

## Atmospheric Infrared Sounder Science Team Meeting

Thomas S. Pagano, AIRS Project Manager, Jet Propulsion Laboratory, [Thomas.S.Pagano@jpl.nasa.gov](mailto:Thomas.S.Pagano@jpl.nasa.gov)

Hartmut "George" H. Aumann, AIRS Project Scientist, Jet Propulsion Laboratory, [Hartmut.H.Aumann@jpl.nasa.gov](mailto:Hartmut.H.Aumann@jpl.nasa.gov)

*The Atmospheric Infrared Sounder (AIRS) Science Team Meeting was held at the Greenbelt Marriott in Greenbelt, MD September 26-29, 2006. All talks are available on the AIRS Project web site—[airs.jpl.nasa.gov](http://airs.jpl.nasa.gov).*

*Tuesday morning was filled with opening talks that gave an overview of the current status of AIRS and the Aqua spacecraft, as well as reports from representatives from NASA HQ.*

**Moustafa Chahine** [Jet Propulsion Laboratory (JPL)—*AIRS Science Team Leader*] welcomed the crowd of approximately 80 guests and shared the motto for AIRS during the build of the instrument: "Always Make Progress." Chahine showed data that appears in an article called "AIRS Improving Weather Forecasting and Providing New Data on Greenhouse Gases" that appears in the July 2006 *Bulletin of the American Meteorological Society* (BAMS). The article breaks down the errors for the near-surface retrieved temperature profile. The results show a cloud clearing error of 0.6 K, a co-location error (with radiosondes) of 0.8 K, and a surface emissivity of 0.9 K. Chahine concludes that the next version of AIRS should focus on improving the surface emissivity retrieval, and expressed his delight for the progress made by the AIRS Science Team and the user community using AIRS data.

**Claire Parkinson** [NASA/Goddard Space Flight Center (GSFC)—*Aqua Project Scientist*] gave a status report on the Aqua Project. The *Earth Science Reference Handbook* is now published, which includes a section that describes the Aqua mission and instruments. The Aqua spacecraft is doing well, but recently terminated a sequence of orbital inclination adjust maneuvers after experiencing unexpected responses in the semi-major axis. Parkinson said that, in terms of fuel, the Aqua mission could probably continue to operate through 2015; however, funding for continuation of the mission will depend on next year's Senior Review. Finally, Parkinson went through the ten Aqua mission success criteria, in each case showing how the mission is doing so far in terms of meeting them. Of the ten, at this point six have been completed. AIRS has two of the ten criteria and will satisfy these with validation of the temperature profiles in the Polar Regions with the *Version 5* release—now expected in January 2007.

**Ramesh Kakar** [NASA Headquarters (HQ)—*Aqua Program Scientist*] said he is "continually amazed by the results" from the AIRS team and that AIRS "continues to set standards for infrared (IR) radiometry." He

expressed his thanks to the team and asked to "keep the results coming." Kakar mentioned the efforts by NASA Headquarters to review the current selection of proposals in the Earth Observing System (EOS) re-compete and was aware of the critical need to make selections as soon as possible. The Senior Review of the Aqua platform is expected to take place in April 2007 along with a review of Terra and the Tropical Rainfall Measuring Mission (TRMM). The AIRS Team Leader Proposal will also be due in April.

**Bruce Doddridge** [NASA HQ—*NASA Program Manager for Tropospheric Chemistry*] expressed his thanks for the "amazing level of support" for the Intercontinental Chemical Transport Experiment (INTEX-B) campaign. AIRS played an important role in this campaign, with Wallace McMillan providing the AIRS analysis for the team.

**Tom Pagano** [JPL—*AIRS Project Manager*] presented science highlights from the last AIRS Science Team meeting and highlighted recent publications by AIRS users. Pagano congratulated recent NASA Award Recipients for their work related to AIRS including Ramesh Kakar who received an Exceptional Service Medal, John LeMarshall of the Joint Center for Satellite Data Assimilation (JCSDA) who received an Exceptional Scientific Achievement Medal, Annmarie Eldering of JPL who received an Exceptional Achievement Medal, and BAE Systems who received a Public Service Group Achievement Award for their development of the AIRS instrument. Finally, Pagano presented a new mission concept called ARIES designed to meet the future requirements of AIRS and the Moderate Resolution Imaging Spectroradiometer (MODIS) in a single instrument.

**Denis Elliott** [JPL—*AIRS Project Operations and Calibration Lead*] said that AIRS and the Advanced Microwave Sounding Unit (AMSU) are operating well with all currents, voltages and temperatures as expected. The only anomaly worth mentioning is an increase of noise in one detector per month beyond the threshold limits, mostly due to radiation effects in orbit.

**George Aumann** [JPL—*AIRS Project Scientist*] presented the objectives of *Version 5*, and showed how the vast majority of objectives defined for *Version 5* in 2004 have been obtained. The most significant improvements are the addition of three new products including the upper tropospheric ozone profile, carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>).

**Chris Barnet** [NOAA] presented the numerous activities happening at NOAA related to AIRS. Barnet's group provides real time support to a wide range of flight and validation campaigns requiring AIRS data. Barnet is also providing data for assimilation studies (Li/Kalnay). NOAA also does its own validation of AIRS data. Finally, NOAA is actively involved in the development of the AIRS Level 2 retrieval including providing regression parameters for surface emissivity and cloud clearing, and development of the trace gas retrieval products. Tom Pagano expressed his thanks on behalf of NASA for the considerable contribution by NOAA and Barnet's team to the AIRS project.

**Joel Susskind** [GSFC] showed the improvement in yield and accuracy of the atmospheric and surface temperatures and water vapor products in *Version 5*.

**Wallace McMillan** [University of Maryland Baltimore County (UMBC)] showed the addition of CO, methane (CH<sub>4</sub>) and ozone (O<sub>3</sub>) profile in *Version 5*. Wallace said the products include *averaging kernels*, which represent a significant improvement over the development products examined earlier. In particular the AIRS CO product is as close to the MOPITT product as could possibly be made.

**Larrabee Strow** [UMBC] presented the progress in the rapid transfer algorithm (RTA) for AIRS that includes a correction to the frequencies of the AIRS M12 module, and the inclusion of the ability to vary CO<sub>2</sub>, nitrous oxide (N<sub>2</sub>O), sulfur dioxide (SO<sub>2</sub>), and nitric acid (HNO<sub>3</sub>). The RTA has also been corrected for non-local thermodynamic equilibrium (Non-LTE) effects.

*Tuesday afternoon was dedicated to trends in the AIRS data since launch in an effort to determine the ability of AIRS to detect global climate signatures.*

**George Aumann** [JPL] showed that the AIRS radiances are stable at about 10 mK/year which qualifies it for being suitable for observing small changes in climate signatures.

**Larrabee Strow** [UMBC] showed the stability of AIRS is sufficient to accurately detect the seasonal variations and annual global rise in CO<sub>2</sub>.

**Mitch Goldberg** [NOAA] shared his limb adjusted radiance products for evaluation of climate forcing, feedback, and response.

**Joel Susskind** [GSFC] showed trends in the *Version 4 Level 3* products that are consistent with other satellite products (e.g. Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS)). These trends include the El-Niño of 2003 and La-Niña of 2006.

**Thomas Hearty** [JPL] showed a small trend (0.1 K/year) in boundary layer air temperature that has steadily increased over the mission and is not reflected in the European Centre for Medium range Weather Forecasting (ECMWF) forecast. There is no explanation for the observed trend in AIRS data at this time.

*The Wednesday morning session was dedicated to assimilation studies using AIRS data.*

**Ron Gelaro** [GSFC Global Modeling and Assimilation Office (GMAO)] presented results from assimilation of the AIRS temperature and water vapor channels into the GEOS-5 data assimilation system. AIRS provides the largest number of observations of all the space instruments assimilated. Assimilation of AIRS radiances has had a net positive impact on forecasts, but further work is required to realize benefit in the water vapor and ozone channels.

**Hong Li and Eugenia Kalnay** [both from University of Maryland] showed that assimilation of AIRS temperature retrievals into the Four Dimensional (4D)-Local Ensemble Transform Kalman Filter (LETKF) has a consistent positive forecast impact in both the southern and northern hemisphere. The LETKF has been shown to be much more accurate than three dimensional models [e.g., Spectral Statistical Interpolation (SSI) Physical-space Statistical Analysis System (PSAS)] and able to efficiently assimilate large numbers of observations. The 4D extension allows the assimilation of satellite data at the right observation time.

**Will McCarty** [University of Alabama, Huntsville] used a method for cloud detection for assimilation of radiances into the regional weather forecasts.

**Brad Zavadsky** [University of Alabama] showed that including AIRS profiles in the assimilation has an overall positive impact of the temperature and moisture fields. During a case study, the AIRS data improved the 53-hour forecast by showing a 4 mb decrease in pressure in the region of the storm as well as improvement in prediction of total rainfall.

**Shanna Sampson** [University of Oklahoma] determined the AIRS filter parameters needed to smooth the comparison data; this resulted in significant improvement in the comparison.

**Bob Rosenberg** [GSFC] showed how assimilating AIRS temperature profiles into the GEOS-5 data assimilation system resulted in an approximately 6-hour average improvement in skill over 26 5-day forecasts in the Northern Hemisphere extra-tropics.

*Wednesday afternoon had several sessions addressing the quality of the AIRS retrievals.*

**Thomas Hearty** [JPL] showed comparisons of the AIRS *Version 4* and *Version 5* retrievals indicating an increase in yield and accuracy near the surface, and a possible reduction in the *dry bias* in the upper troposphere.

**Hengchun Ye** [California State University Los Angeles] gave the first look into the performance of the AIRS total precipitable water in the Polar Regions. Results show AIRS compares well with radiosondes and ECMWF.

**Eric Fetzer** [JPL] showed comparisons of AIRS and Microwave Limb Sounder (MLS) water vapor in the upper troposphere. Results show agreement to a few percent at the 250-mb level where MLS and AIRS should have common sensitivity. Above 250 mb the AIRS loses sensitivity, and below this, the MLS shows a dry bias.

**Fengying Sun** [NOAA] showed the value of convective products [e.g. Convective Available Potential Energy (CAPE)] and recommended production of such products for AIRS.

**Lihang Zhou** [NOAA] presented her results on generating regression coefficients for the AIRS *Version 5* system. A major part of this was updating the surface emissivity training set. Zhou's efforts also produced a very good regression solution for the AIRS-only (i.e., no AMSU) backup retrieval system.

**Antonia Gambacorta** [UMBC] examined the effects of spatial gradients when comparing AIRS to radiosondes, and concluded that only radiosondes within 50 km of the AIRS retrievals should be considered. Working with the retrieval, Gambacorta also realized that the retrieval may be over damped in its present configuration.

**Bill Blackwell** [Massachusetts Institute of Technology, Lincoln Labs] presented recent progress in stochastic cloud clearing and a neural network retrieval algorithm. His temperature retrievals compared better with ECMWF than the AIRS retrieval system.

**Mike Theobald** [Goddard Earth Sciences Data and Information Services Center (GES/DISC)] gave a status report on the processing currently being performed at the GES/DISC in support of AIRS. The GES/DISC is moving towards *Linux* clusters and expect to soon be able to process AIRS data at 10x—10x means 10 days of AIRS data in 1 day. Theobald also announced that the GES/DISC now is processing AIRS data in *real time* for limited distribution, and with predicted ephemeris. The GES/DISC has provided outstanding support of the AIRS Project since the start of AIRS operations—e.g., supporting user services, developing online applications, data processing and distribution.

**Steve Friedman** [JPL] led the session on planned improvements for *Version 6*. He showed the current delivery schedule for *Version 5* and a plan for *Version 6*.

**Joel Suskind**, [GSFC] presented performance updates on the AIRS-Only retrieval system and had suggestions for *Version 6* including improving surface parameter retrieval and a higher spatial resolution product.

**Chris Barnet** [NOAA] suggested several other improvements including removing biases, better use of the microwave data, and implementation of new trace gas products.

**Larrabee Strow** [UMBC] also suggested including new trace gas products and aerosols in *Version 6*, but also suggested a “Level 1C” be created to provide radiances on a fixed frequency set for climate users.

*Thursday morning was dedicated to the evaluation of the composition products from AIRS.*

**Eric Maddy** [NOAA] presented the *averaging kernels* for *Version 5*. They represent a major improvement over prior versions, and when used properly, he showed how they improve comparisons with sondes.

**Bill Irion** [JPL] presented the differences in the *Version 4* and *Version 5* ozone product. *Version 5* reduces biases, but still has difficulty in regions with less than 100 parts per billion by volume (ppbv) of ozone. The retrieval appears to be *over damped* indicating that the information content is there, but to obtain it the retrieval needs to be relaxed a bit.

**Murty Divakarla** [NOAA] presented comparisons of AIRS retrievals with ozonesondes and shows the information content in AIRS is better than ECMWF. AIRS does show biases below 200 mb, but does well above that level.

**Laura Pan** [National Center for Atmospheric Research (NCAR)], showed comparison of AIRS ozone with radiosondes and aircraft observations. Pan also sees the bias in AIRS data below 200 mb, but indicates AIRS shows good sensitivity in the 70–250 mb region. AIRS data in its current form shows tremendous value in studying the Stratospheric-Tropospheric Exchange (STE).

**Baijun Tian** [JPL] presented results from a study of the intraseasonal variations of the tropical total ozone using AIRS and Total Ozone Mapping Spectrometer (TOMS) data. Tian's findings show that there is a clear Madden-Julian Oscillation (MJO) in the tropical total ozone. The maxima of the total ozone MJO anomalies are located over the subtropics and are dynamically driven by the size and magnitude of subtropical cyclones or anticyclones associated with the equatorial MJO convection.

**Mous Chahine** [JPL] presented *beta* retrievals of mid-tropospheric CO<sub>2</sub> using the method of Vanishing Partial Derivatives. The results show good comparison with models in the mid latitudes, but a significant difference in the southern hemisphere. The European Space Agency's SCanning Imaging Absorption spectroMeter for Atmospheric ChartographY (SCHIAMACHY) instrument on ENVISAT shows a similar result to AIRS. Modelers at California Institute of Technology (CalTech) and JPL are working with Chahine to understand the differences.

**Scott Hannon** [UMBC] presented first results of his SO<sub>2</sub> and HNO<sub>3</sub> retrievals from AIRS. The sensitivity of AIRS to SO<sub>2</sub> is 1 Dobson Unit, which makes it primarily useful for detecting high concentrations of SO<sub>2</sub> such as volcanoes. AIRS sensitivity to HNO<sub>3</sub> is similar to SO<sub>2</sub>, except sensitivity to HNO<sub>3</sub> may be higher in the lower troposphere.

**Wallace McMillan** [UMBC] presented results of validation of AIRS carbon monoxide. AIRS CO and O<sub>3</sub> were used in the second TEXas Air Quality Study (TEXAQS-II) to support flight planning. The AIRS data, when combined with modeled data, are useful for predicting regional air quality. For example, fires in Louisiana were found to be contributing to reduced air quality in Houston. The integration of AIRS O<sub>3</sub>, CO and H<sub>2</sub>O were helpful in understanding the accuracies of the retrieved individual quantities.

**Jennifer Wei** [NOAA] showed how AIRS captures stratospheric intrusions from tropospheric folds—similar to Laura Pan's work. Wei's analysis of the retrieval indicates that the physical retrieval can be improved with the addition of more AIRS ozone channels, and the reduction in the amount of damping.

**Xiaochen Xiong** [NOAA] presented some of the first results from the AIRS CH<sub>4</sub> retrieval. Xiong's results show good agreement with aircraft and models, and was able to see an increase in CH<sub>4</sub> over Canada and the Tibetan plateau in summer.

*Thursday afternoon included a presentation from the EOS Senior Project Scientist on MODIS atmosphere products, as well as more talks on AIRS research.*

**Michael King** [GSFC—EOS Senior Project Scientist] gave an invited presentation on the atmosphere products from MODIS. MODIS has superb atmospheric products including cloud, aerosol and water vapor products. King's presentation was especially appreciated and stimulated dialogue amongst team members on how to use MODIS more effectively.

**Sergio DeSouza-Machado** [UMBC] compared transmittance in dust regions from AIRS and MODIS and gets very good agreement. The AIRS Outgoing

Longwave Radiation (OLR) shows correlation with the AIRS dust score.

**Brian Kahn** [JPL] presented results from examining AIRS cirrus particle size compared to *in-situ* and MODIS measurements. The AIRS cloud top heights also compare well with CloudSat data.

**Nick Nalli** [NOAA] shared information about his exciting venture on board the NOAA ship, the *Ronald H. Brown* as part of the AEROS campaign. The cruise of the central Atlantic Ocean covered periods of May through July, 2006. The primary mission was to place two ocean moorings, but numerous radiosonde, ozonesonde, smoke, dust, and surface observations were made along the way.

**Evan Fishbein** [JPL] presented his evaluation of the AIRS cloud-cleared radiances compared to ECMWF and emissivities, comparing them to models.

**Bob Knuteson** [University of Wisconsin] compared the land surface temperature retrievals from AIRS to observations at the ARM Southern Great Plains Central Facility. Results compare well with a 1 K bias at night. Surface emissivity was also examined but, as expected, needs more work.

*The Friday morning session ended the meeting and included discussions of validation and calibration of AIRS.*

**Jim Yoe** [NOAA] showed "remarkable" agreement between AIRS and Global Positioning System (GPS) total water vapor measurements.

**George Aumann** [JPL] compared AIRS, MODIS and HIRS radiances over Antarctica with good precision.

**Larrabee Strow** [UMBC] showed the spectral stability of AIRS to be about 6 parts per million (ppm) over the life of the mission—the rate is decreasing significantly with time—but Strow believes that in order to see climate signatures, even this small amount needs to be accounted for.

**Denis Elliott** [JPL] presented a technique to use the AIRS pre-flight spatial response measurements to overlay MODIS and AIRS radiances to better than 1 K [1 standard deviation ( $\sigma$ )] in non-uniform scenes.

**Haibing Sun** [NOAA] also showed improvement using a simulated spatial response function and that AIRS can be used to determine the Aqua/MODIS spectral response functions in orbit.

**Dave Whiteman** [GSFC] presented results from Water Vapor Variability—Satellite/Sondes (WAVES) 2006,

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## Aura Science Team Meeting Summary

Anne Douglass, NASA Goddard Space Flight Center, [Anne.R.Douglass@nasa.gov](mailto:Anne.R.Douglass@nasa.gov)

An Aura Science Team Meeting was held in Boulder, CO, September 11-15, 2006, and attracted more than 225 participants—by far the largest attendance ever. Science presentations, including all oral presentations and many of the posters described below, may be obtained at [avdc.gsfc.nasa.gov/Overview/index.html](http://avdc.gsfc.nasa.gov/Overview/index.html), the Aura Validation Data Center. The next Aura Science Team Meeting will be during the week of October 1-5, 2007, in Pasadena CA.

The meeting agenda had several elements: updates on the operations and data quality for each of the four instruments, science presentations, and breakout meetings for aerosols and clouds, air quality, data systems, education and public outreach, mission operations, meteorological and assimilated projects, and validation. The Validation Working Group consisted of nine different subgroups. The meeting began with welcomes from **Tim Killeen** [National Center for Atmospheric Research (NCAR)—*Director*], and from meeting host, **John Gille** [NCAR—*Co-Principal Investigator (PI) of the High Resolution Dynamic Limb Sounder, U.S.*]

The opening talks presented updates on the instruments on Aura from the instrument PI's and an update on the status of validation efforts related to Aura:

- **Gille and John Barnett** [Oxford University—*Co-PI of the High Resolution Dynamics Limb Sounder (HIRDLS), U.K.*] provided an update on operations and data retrieval from HIRDLS.
- **Joe Waters** [NASA/Jet Propulsion Laboratory (JPL)—*PI for the Microwave Limb Sounder (MLS)*] announced that he is retiring and passing on the leadership of MLS to **Nathaniel Livesey** [JPL]. The new MLS PI provided an overview of MLS status, operations, and a survey of some scientific results. A new version of the MLS retrieval algorithm will be implemented in November 2006; this version requires delivery of *Version 5* of the Goddard Earth Observing System data assimilation system (GEOS-5).
- **Pieter Levelt** [Koninklijk Nederlands Meteorologisch Instituut (KNMI)—*PI for the Ozone Monitoring Instrument (OMI)*] reported that a number of milestones must be met before reprocessing of the calibrated geolocated (Level 1B) data can begin, with a target start date of January 2007. Many of the OMI products have been publicly released and there are worldwide users of near-real-time products such as the nitrogen dioxide (NO<sub>2</sub>) column.
- **Reinhard Beer** [JPL—*PI of the Tropospheric Emission Spectrometer (TES)*] showed that the warming of the optical bench that took place last December

dramatically improved the information retrieved on carbon monoxide (CO). TES nadir products for ozone (O<sub>3</sub>), and CO are considered validated; temperature, water (H<sub>2</sub>O) and deuterium (HDO) are provisionally validated. Limb products including nitric acid (HNO<sub>3</sub>), O<sub>3</sub>, and temperature and the nadir product for methane (CH<sub>4</sub>) are still preliminary. TES data will be reprocessed beginning in the next year and, like MLS, requires delivery of GEOS-5.

- **Bojan Bojkov** [NASA Goddard Space Flight Center (GSFC)] presented the status of the Aura Validation Data Center, and requested information from the science teams on new data products and validation datasets.

Monday and Tuesday's sessions were devoted to science presentations, primarily focusing on tropospheric observations and their interpretation.

- **Hanwant Singh** [NASA Ames Research Center] summarized the Aura validation observations that were obtained during the Intercontinental Chemical Transport Experiment (INTEX-B), a NASA aircraft mission that took place during Spring 2006.
- **Lin Zhang** [Harvard University] used O<sub>3</sub>-CO correlations to interpret continental outflow and intercontinental transport of O<sub>3</sub> pollution from TES.
- **Folkert Boersma** [KNMI] described the near-real-time tropospheric NO<sub>2</sub> observations from OMI during INTEX-B.
- **Dylan Jones** [JPL] discussed assimilation of TES observations of CO and O<sub>3</sub> into GEOS-CHEM to investigate how sensitive tropospheric O<sub>3</sub> is to changes in emissions in the tropical Atlantic.
- **Daniel Jacob** [Harvard] explained how the OMI formaldehyde (H<sub>2</sub>CO) measurements provide information about isoprene emissions, and how these data reveal problems in the emission inventories.
- **Brian Duncan** [GSFC] showed that the Global Modeling Initiative Combined Chemistry and Transport Model reproduced features in CO observed by MLS and Measurements of Ozone and water vapour by in-service Airbus airCraft (MOZAIC), and then used chemical transport model (CTM) results to study impact of pollution generated by the 1997 Indonesian fires.
- **Jerry Ziemke** [GSFC] used nearly two years of Aura OMI O<sub>3</sub>, MLS, H<sub>2</sub>O, and CO measurements to show that the tropospheric ozone variability in the tropical Pacific upper troposphere is dominated by the Madden-Julian Oscillation (MJO).

- **Sun Wong** [Texas A&M University] used data from MLS to relate the MJO and outgoing longwave radiation (OLR) anomalies to H<sub>2</sub>O anomalies.
- **Mark Schoeberl** [GSFC—*Aura Project Scientist*] showed a tropospheric ozone product that is the difference between the stratospheric column derived from MLS profiles using trajectory mapping to produce a dense grid and the OMI total column. This work showed that it is important to synchronize the OMI measurements and the stratospheric column to avoid misplacement of tropopause folds.
- **Jennifer Logan** [Harvard] showed that the CO prior constraints used in retrieval have an impact on the retrieved products; the use of a *uniform prior* vs. the use of a different prior in different regions is a particularly important issue because the Measurements of Pollution in the Troposphere (MOPITT) instrument on Terra uses a *uniform prior* and TES uses a spatially varying prior from the Model for Ozone and Related Chemical Tracers (MOZART) CTM.
- **Ming Luo** [JPL] stressed the need for a working plan to deal with the impact of the *a priori* information that was visible in the fields she presented.
- **Curtis Rinsland** [NASA Langley Research Center (LaRC)] gave an introduction to the Atmospheric Chemistry Experiment (ACE) on Canadian SciSat and showed retrievals of constituents produced during biomass burning.

Wednesday morning science talks focused on processes associated with tropical water vapor and ice.

- **Michael Schwartz** [JPL] showed that the MLS ice water content exhibits a Madden-Julian oscillation, and questioned if the MJO actually dominates the variability in temperature, water vapor, and ice.
- **Eric Ray** [JPL] used water vapor measurements from MLS and the Atmospheric Infrared Sounder (AIRS) to investigate the impact of tropical storms on water vapor amounts in the subtropical troposphere.
- **Andrew Gettelman** [NCAR] compared observations of ice supersaturation for AIRS and from both the Upper Atmosphere Research Satellite (UARS)/MLS and Aura/MLS instruments with results from a coupled chemistry climate model.
- **Thomas Hanisco** [Harvard] used *in situ* observations of H<sub>2</sub>O and HDO from the NASA WB-57 and remote measurements of H<sub>2</sub>O from Aura/MLS in conjunction with a Lagrangian model to evaluate the role of convection in determining the stratospheric water budget. The atmospheric  $\delta D$  does not decrease with altitude above 12-14 km; the stratospheric entry value is important because

it tells the fraction of water in the stratosphere that enters the region as ice vs. vapor.

- **Darryn Waugh** [Johns Hopkins University] used MLS and AIRS measurements of H<sub>2</sub>O and O<sub>3</sub> to examine variability in the subtropical upper troposphere, and showed that the driest subtropical areas have the least variability—and vice versa.
- **Leonard Pfister** [GSFC] examined the same midwinter period from two years with different temperature and water vapor values to see how well the periods could be simulated with conventional microphysics. Although the simulations reproduce much of the variability seen in MLS, there are systematic differences between the MLS water and aircraft measurements that suggest inadequacies of the conventional microphysical approach.

The Thursday plenary presentations included 4 science talks and 12 validation talks of general interest.

In the science talks:

- **Daniel Feldman** [California Institute of Technology] compared the ice cloud contribution to cloud forcing calculated from MLS ice water content with observations from Clouds and the Earth's Radiant Energy System (CERES) on Aqua.
- **Mijeong Park** [NCAR] considered tracer variability above the Asian summer monsoon anticyclone using MLS measurements of H<sub>2</sub>O, O<sub>3</sub> and CO during the northern hemisphere summer.
- **Rong Fu** [Georgia Institute of Technology] showed results of a trajectory analysis using MLS water vapor measurements at 100 hPa for the summers of 2004 and 2005, to assess the cause of the *tape recorder* in the Asian monsoon/Tibet region and to determine its relation to the global tropical *tape recorder* signal.
- **Kaley Walker** [University of Waterloo] reported on the status of the Atmospheric Chemistry Experiment (ACE) mission, and showed that ACE O<sub>3</sub> profiles look good with respect to ozonesondes down to 6-8 km. Walker also showed profiles of methanol (CH<sub>3</sub>OH), a signature of biomass burning and other constituents important for air quality in the upper troposphere.

In the plenary validation talks:

- **Er-Woon Chiou** [LaRC] showed detailed comparisons of monthly zonal mean total column ozone from OMI using the Total Ozone Mapping Spectrometer (TOMS) *Version 8* algorithm and the Different Optical Absorption Spectroscopy (DOAS) algorithm with observations from the NOAA-16 Solar Backscatter Ultraviolet (SBUV/2) instrument.

- **Kenneth Jucks** [Harvard-Smithsonian Center for Astrophysics] showed results from balloon flights of the Far-Infrared Spectrometer (FIRS-2) on September 23-24, 2004, and September 20-21, 2005 from Fort Sumner, NM. The FIRS-2 H<sub>2</sub>O results generally match the frost point sondes, adding to the puzzle of differences between the frost point sondes and the aircraft instruments.
  - **Jim Gleason** [GSFC] showed the status of the validation of the OMI NO<sub>2</sub>, noting the particular challenges in polluted areas and highlighting the need for additional validation data.
  - **Mark Parrington** [British Atmospheric Data Center] used assimilation of the TES data to consider the processes controlling distributions of O<sub>3</sub> and CO.
  - **Robert Stachnik** [JPL] showed comparisons of bromine monoxide (BrO) from the balloon-borne sub-millimeter-wave Limb Sounder with measurements from MLS.
  - **Geoff Toon** [JPL] showed many comparisons of Aura measurements with profiles obtained from the JPL *MkIV* interferometer balloon flights from Fort Sumner, NM in September 2004 and 2005.
  - **Mark Kroon** [KNMI] summarized results from the European announcement of opportunity for validation of OMI data, showing some good comparisons and broad participation from the European community.
  - **Claire Waymark** [Oxford] showed comparisons of HIRDLS and Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) radiances for the 10 HIRDLS channels that are completely covered by the MIPAS spectral bands, and showed agreement with the present HIRDLS radiance after correction for the Kapton<sup>®</sup>.
  - **David Whiteman** [GSFC] showed comparisons of Aura measurements of water vapor and ozone with observations obtained during the Water Vapor Validation Experiment—Satellite/Sondes (WAVES-2006).
  - **Gordon Labow** [Science Systems and Applications Inc. (SSAI)/GSFC] used observations of ozone, aerosols, and cloud heights made during the INTEX-B field experiment to validate OMI products. Preliminary results show that all satellite cloud products have problems in the presence of multi-layered clouds.
  - **Shuntai Zhou** [NOAA NCEP] compared ozone and temperature from the National Center for Environmental Prediction (NCEP) global data assimilation system that uses ozone profile data from SBUV/2 instruments with observations from MLS. Comparisons are generally good except in polar night, where SBUV/2 does not observe and the assimilation model disagrees with MLS ozone by up to 50%.
  - **Ben Veihelmann** [KNMI] spoke on behalf of **Johan deHaan** [KNMI] and showed first results of the OMI ozone profile algorithm and comparisons with ozone sondes and MLS profiles.
- This session was followed first by a discussion to examine outstanding issues, which are summarized in the final paragraphs of this report, and the final poster session.
- The final science session took place Friday morning.
- **Om Tripathi** [JPL] presented a comparison of lower stratospheric ozone observed by MLS with that modeled using a French model called Méso-échelle de l'Ozone Stratosphérique par Advection—chemistry-extended version (MI-MOSA-CHIM). The JPL lidar and MLS both observed a filament of polar ozone that reached 20°N latitude in March 2005.
  - **Craig Benson** [UMBC] compared MLS HNO<sub>3</sub> with a simulation using the GSFC CTM, investigating the reasons that the CTM produces an early winter polar stratospheric cloud for which there is no observational evidence.
  - **Simon Carn** [Joint Center for Earth Systems Technology] showed that OMI measures SO<sub>2</sub> not only in explosive volcanic eruptions but also can detect passive volcanic degassing. There is evidence that sulfate aerosols produced from volcanic SO<sub>2</sub> brighten clouds.
  - **David Sayres** [Harvard] used measurements of H<sub>2</sub>O and HDO from the NASA WB-57 made during the Costa Rica—Aura Validation Experiment (CRAVE) along with measurements of H<sub>2</sub>O from MLS to assess exchange between the upper tropical transition layer and the latitudes higher than that of the subtropical jet.
  - **Ivanka Stajner** [Science Systems and Applications Inc./GSFC] reported on differences in the tropospheric ozone column derived from an assimilation system depending on how the tropopause is defined.
  - **Hui Su** [JPL] analyzed observations of upper tropospheric clouds, sea surface temperatures, water vapor, and ice from Aura/MLS and Aqua/AIRS to revisit the so-called *Iris Hypothesis* in which the upper tropospheric cloud fraction decreases with increasing sea surface temperature, theoretically leading to a negative climate feedback. There is a negative correlation between the upper tropospheric clouds with sea surface temperature, and radiative transfer calculations show that this is a positive climate feedback.
  - **John Worden** [JPL] showed that combined ultraviolet information from OMI with infrared information from TES is more sensitive to lower tropospheric ozone than TES alone.



Other highlights of the meeting included a discussion of an upcoming NASA mission, Tropical Composition, Cloud and Climate Coupling (TC4), planned for summer 2007. The Earth Observing System Project Science Office will coordinate with the instrument teams to set validation for these flights. Other validation issues such as the need for additional measurements of the NO<sub>2</sub> column in polluted areas were clarified in the meeting and are being addressed.

### Working Group Summaries

Summaries of each of the working group meetings and the validation subgroup meetings are given below. The name of the chairperson of each working group session is listed in brackets after the title.

#### *Aerosol Validation and Working Group* [**Steve Massie**—NCAR]

The eleven presentations in the Aerosol/Cloud/SO<sub>2</sub> session focused on data set improvements, validation challenges, and ongoing developments. Improvements in MLS ice water content (IWC) and (TES - MODIS) cloud top pressure differences were presented. The challenges of validating HIRDLS vertical profiles of cirrus extinction and MLS IWC fields with *in-situ* aircraft and other satellite data were discussed. Finally, an ongoing analysis that uses additional OMI wavelengths to retrieve additional aerosol parameters was presented, and typifies how current algorithms can be extended and improved.

#### *Air Quality Working Group* [**Ken Pickering**—University of Maryland, College Park]

Nearly 60 people attended the first meeting of the Aura Air Quality Working Group, reflecting substantial interest in applications of Aura data for this purpose. The group meeting included seven short talks focused mostly on tropospheric ozone and discussions of objectives and needs to improve usefulness of Aura data for air quality applications. Issues concerning use of Aura data include uncertainty in defining the tropopause for development of tropospheric data products, and how well Aura data compare with surface observations. It is agreed that the best use of Aura data is together with surface observations and an air quality model in a comprehensive assimilation system.

#### *Data Systems Working Group* [**Cheryl Craig**—NCAR]

The main items of interest to this year's Data Systems Working Group were the final modification to the Aura Hierarchical Data Format for the Earth Observing System (HDF-EOS) Guidelines to include Grid and Zonal Mean product definitions, as well as the evolution of the Goddard and Langley Data and Information

Service Centers (DISCs). Participants also exchanged information that other instrument teams would find useful in regards to our data processing.

#### *Education and Public Outreach* [**Stephanie Stockman**—GSFC]

Presentations included an overview by the chairperson of the Aura post-launch Education and Public Outreach (EPO) program, including the ozone monitoring garden project. **David Brooks** [GLOBE/Drexel University] reported on scientist-teacher-student partnerships, including an instrument training workshop at GSFC for educators, a NOAA workshop on aerosols for students and teachers in support of the Texas Air Quality/Gulf of Mexico Atmospheric Composition and Climate Study (TEXAQS/GoMACCS) field campaign, and the status of Aura sponsored instruments used in these activities. **Folkert Boersma** [KNMI] reported that the GLOBE Aerosol program has expanded in the Netherlands, and the Aerosol Module is now part of the science curriculum in Dutch schools. A high school student participating in the GLOBE program collected data that is used in a 2006 *Journal of Geophysical Research (JGR)* paper on Moderate Resolution Imaging Spectrometer (MODIS) aerosol validation. **Aapo Tanskanen** [Finnish Meteorological Institute (FMI)] reported for the FMI OMI team on the use of OMI direct broadcast data to create very fast delivery of total ozone, UV-index and Erythema daily dose. Direct broadcast data promotes public interest in the science mission and is useful when fast decisions are required.

#### *Meteorological Products Working Group* [**Gloria Manney**—JPL]

The Meteorological Products Working Group (MPWG) fosters communications and interactions between the Aura instrument teams and the providers of meteorological data products [primarily NOAA/NCEP and the Global Modeling and Assimilation Office (GMAO)]. Updates on changes in the NCEP and GMAO assimilation systems were presented. Aura instrument teams use these and other meteorological datasets for various applications. The primary issue discussed was the schedule of GMAO's transition from GEOS-4 to GEOS-5. This is a major change in the analysis system and the schedule is important because several Aura teams are using these data. MLS and TES plan to use GEOS-5 data in their new retrieval software versions and the instrument teams need to be able to reprocess data for discussion in the special validation issue of *JGR* planned for Spring 2007.

#### *Mission Operations Working Group* [**Angie Kelly**—GSFC]

The Aura Mission Operations Working Group (MOWG) met on September 12. Each of the instrument teams

provided a summary of activities and events for the past year and discussed the challenges and lessons learned in the resolution of some anomalies. HIRDLS also presented the rationale for performing periodic pitch maneuvers—the next one is planned for November 3. All the instruments and the spacecraft bus are currently in nominal operations mode.

Two key items were discussed: the ongoing re-engineering of the interfaces with the Mission Management (scheduling) system, and the proposed *automatic operations (auto ops)* of the Solid State Recorder (SSR). The ongoing re-engineering activity will improve the security of the control center and the remote instrument facilities. The proposed *auto ops* of the SSR will help mission operations cope with the reduced operations budget. However, depending on the way each instrument packet is formatted, *auto ops* may lead to data loss for some of the instruments—up to 15 packets per day or one per orbit. GSFC is looking into a solution to avoid data loss. Each of the instrument/science teams will evaluate the impact on their science data products and provide a write-up to the Aura Project Scientist.

#### *Chlorine Validation* [Lucien Froidevaux—KNMI]

The chlorine validation subgroup session included presentations on OMI chlorine dioxide (OCIO) and updated comparisons of MLS chlorine monoxide (ClO), hydrochloric acid (HCl), and hypochlorous acid (HOCl) with correlative observations. The OMI OCIO product is planned for public release in October 2006, and the definitive *Version 2* MLS products are planned for November 2006. Preliminary OMI OCIO slant columns are similar to those retrieved by SCanning Imaging Absorption spectroMeter for Atmospheric ChartographY (SCIAMACHY). There are no major changes in the MLS chlorine products, despite a few differences from the previous version. HOCl averages are still considered useful only in the upper stratosphere. For MLS HCl, reprocessing since the Aura launch is necessary for careful time series analyses across mid-February 2006, after which the HCl product depends only on the radiances from an alternate MLS filter bank.

#### *CO Validation* [Ming Luo—JPL]

Presentations were made for validations of TES nadir troposphere *Version 2* CO and MLS upper troposphere and upper stratosphere/mesosphere *Version 2* CO products. TES CO data has been compared to MOPITT, AIRS, MLS, ACE satellite data and the *in-situ* measurements in INTEX-B, AVE, and MOZAIC campaigns. Differences among measurements are much smaller than the area variability of the CO fields. Comparisons between TES CO and that retrieved by MOPITT and AIRS are complicated by the influences of *a priori* constraints on the remote sensing retrievals. Analyses of limited MLS

*Version 2* data show much improvement over *Version 1.5* comparing to correlative measurements.

#### *H<sub>2</sub>O and N<sub>2</sub>O Validation* [Karen Rosenlof—NOAA Earth System Research Laboratory, Chemical Sciences Division]

TES H<sub>2</sub>O values for *Version 2*—current retrieval available at the DISC—are 10-25% wetter than AIRS in the troposphere between 150 and 500 hPa, 15-20% drier than AIRS between 500-1000 hPa, and 0-30% wetter than values acquired by radiosondes at the Department of Energy's Atmospheric Radiation Measurement (ARM) sites from 100-700 hPa. MLS N<sub>2</sub>O values for planned *Version 2* are ~10% larger than *Version 1.51*—current retrieval available at the DISC—giving overall better agreement with other satellite measurements. MLS *Version 2.10* H<sub>2</sub>O values are ~0.5 parts per million by volume (ppmv) higher at all altitudes as compared with *Version 1.51*. The MLS H<sub>2</sub>O values at the 464 and 681 mb levels are still not deemed reliable; work will continue on improving those retrievals. HIRDLS water vapor values are reasonable, although issues remain and much further refinement is needed. Differences were also noted among *in situ* measurements, in particular recent AVE aircraft measurements and balloon measurements at low water vapor mixing ratios. These differences are presently unexplained, and it is unknown which measurements are more reliable.

#### *HNO<sub>3</sub> Validation* [Michelle Santee—JPL]

HIRDLS, TES, and MLS gave status reports on their respective HNO<sub>3</sub> products. TES and MLS HNO<sub>3</sub> were compared to the University of New Hampshire SAGA *in situ* measurements obtained on Aura underpasses during the Polar Aura Validation Experiment (PAVE) and INTEX-B campaigns. Comparisons of HIRDLS HNO<sub>3</sub> with balloon, aircraft, and satellite datasets show good agreement in the overall morphology of the distribution, although HIRDLS HNO<sub>3</sub> appears to have some significant biases, particularly in the middle and upper stratosphere. TES HNO<sub>3</sub> limb retrievals have been extended down into the upper troposphere in *Version 3*, and initial profile comparisons look promising. MLS HNO<sub>3</sub> data have been greatly improved in *Version 2*. The profiles are considerably smoother than those from *Version 1.5*; unrealistic behavior at the lowest retrieval levels has been substantially reduced, and the ~30% high bias caused by a spectroscopy error in the previous version has been corrected.

#### *Radiance and Forward Model Validation* [Tony Clough—Atmospheric and Environmental Research, Inc.]

Accuracy of atmospheric parameter retrievals is critically dependent on the accuracy of the measured spectral radiances and the Forward Model radiances. Radiance

validations between TES and Scanning High-Resolution Interferometer Sounder (S-HIS)—used in AVE—between TES and AIRS, and between TES and forward model calculations with sonde and GMAO/European Centre for Medium Range Weather Forecasting (ECMWF) defined atmospheres were all presented. S-HIS data were considered invaluable, and the differences are now remarkably small (on the order of 0.1 K in brightness temperature). Comparisons between HIRDLS radiance and HIRDLS forward model calculations using ECMWF fields were also presented. The results were most encouraging and could be explained by a 1.5 km pointing adjustment. The subgroup felt that coordination with other Aura science teams would be most useful—e.g. with Aqua.

#### *Radicals Validation* [Ross Salawitch—JPL]

Profiles of NO<sub>2</sub> (from HIRDLS), BrO (from MLS), hydroxide (OH) and hydroperoxyl (HO<sub>2</sub>) (from MLS), and columns of NO<sub>2</sub> and BrO columns (from OMI) were considered in this discussion. OMI column NO<sub>2</sub> correlates with ground-based data, but OMI NO<sub>2</sub> is 20-30% less than ground-based data for highly elevated columns. The OMI team is investigating this difference, including the role of aerosol absorption. Column NO<sub>2</sub> measurements from various ground-based instruments are being inter-compared presently in Europe; another inter-comparison is being planned for Table Mountain, CA during May and June 2007 (please contact Stan Sander [JPL] if interested in participating). HIRDLS NO<sub>2</sub> profiles exhibit features similar to ACE profiles. HIRDLS retrievals are 10-100% lower than NO<sub>2</sub> measured by ACE at sunrise or sunset without accounting for the difference in local solar time. Maps of total column BrO from OMI (*Version 0.9.50*) indicate bromine release from ice shelves and salt lakes. MLS measurements of BrO profiles, from the *BinRad* adjunct to *Version 1.5* retrievals, compare well with profiles measured by the DOAS and Système D'Analyse par Observations Zénithales (SAOZ) balloon instruments. Finally, MLS *Version 2.1* retrievals provide higher vertical resolution for mesospheric OH and smoother retrievals for stratospheric HO<sub>2</sub> than prior versions. *Version 2.1* profiles of OH and HO<sub>2</sub> are consistent with expectations from simulations, unlike prior measurements of OH profiles obtained by the shuttle-borne Middle Atmosphere High Resolution Spectrographic Investigation (MAHRSI) instrument that were inconsistent with simulations. Those inconsistencies became the so-called HO<sub>x</sub> dilemma, now apparently resolved.

#### *Stratospheric Ozone Validation* [Ray Wang—Georgia Tech.]

The provisional MLS *Version 2.1* ozone product shows better agreement compared to correlative measurements including ozonesondes and Stratospheric

Aerosol and Gas Experiment (SAGE II) than *Version 1.5* retrievals. Measurements are within 5% from 0.15-100 hPa and ~10% at 150 hPa. The HIRDLS (*Version 2.02*) ozone shows low biases of less than 10% from 2-20 hPa. The HIRDLS retrieval team has proposed several different procedures to correct the larger negative—and increasing with decreasing altitude—biases for ozone below 20 hPa.

#### *Temperature Validation* [Steven Pawson—GSFC]

Many types of temperature data are available for Aura validation, ranging from *in-situ* measurements (e.g., sondes, aircraft sensors), surface or aircraft-based lidars and remote sounders, other space-based instruments, and meteorological analyses. The presentations in the Temperature Validation Working Group used all of these data types for evaluation of Aura retrievals, highlighting a number of biases and discrepancies. While some of these differences appear to be reduced when prototype versions of the next retrieval algorithms are used, others are not and there are potentially fruitful research pathways for the community to understand the reasons for these differences.

#### *Total Ozone and Tropospheric Ozone Validation* [Richard McPeters—GSFC, Mark Kroon—KNMI]

OMI total column ozone agrees with ground-based measurements to within 1%. Current issues with total ozone column accuracy included the influence of clouds and of bright snow surfaces, and profile shape at high latitudes. TES ozone profiles have a positive bias in the lower to mid-troposphere of less than 10% that will be addressed in *Version 3*. ■

## AIRS Science Team Meeting

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which involved validating AIRS using raman lidar, radiosondes, and ozonesondes.

**Ed Olsen** [JPL] discussed plans for providing a user guide for the AIRS *Version 5* delivery.

*The AIRS Science Team Meeting was a tremendous success with over 50 presentations by government and universities. Presenters shared their hard work developing and validating the numerous products from AIRS with almost all results favorable. The AIRS experiment is paving new territory for high spectral resolution infrared observations of the Earth in support of NASA global Earth Science, climate, and weather forecasting. The next team meeting is scheduled for March 6 - 9, 2007, at CalTech in Pasadena, CA, and will focus on the scientific discoveries being made with AIRS data.* ■

## OMI Science Team Meeting Summary

Mirna van Hoek, Koninklijk Nederlands Meteorologisch Instituut, [hoekvw@knmi.nl](mailto:hoekvw@knmi.nl)

Joanna Joiner, NASA Goddard Space Flight Center, [joanna.joiner@nasa.gov](mailto:joanna.joiner@nasa.gov)

*The Eleventh Ozone Monitoring Instrument (OMI) Science Team Meeting was held from June 20-22 at the Royal Netherlands Meteorological Institute [Koninklijk Nederlands Meteorologisch Instituut (KNMI)] in De Bilt, The Netherlands. The number of people who registered for the meeting was 80. The first day included status reports from the different working groups (WG) and was followed by WG meetings. The second day was devoted to workshops for different OMI products and an OMI group summary, discussion, and outlook meeting. On the third day there were summaries of the workshops followed by the Validation Working Group meeting. A detailed summary of the meeting follows. Additional information is available at: [www.knmi.nl/omi/research/project/meetings/ostm11/](http://www.knmi.nl/omi/research/project/meetings/ostm11/)*

### June 20

**Frits Brouwer** [KNMI—*Director*] opened the meeting and greeted participants.

**Pieterneel Levelt** [KNMI—*OMI Principal Investigator (PI)*] gave a first glimpse of a possible future European Space Agency (ESA) Core Explorer satellite called Tropospheric composition and Air Quality (TRAQ), followed by an overview of OMI history. As part of the OMI project status report, important changes in the OMI Science Team were mentioned. Bert van den Oord [KNMI—*OMI Deputy PI*] is leaving the team to become a Division Head in the KNMI department infrastructure. Pepijn Veeffkind [KNMI] will succeed him as the new Deputy-PI. Marcel Dobber [KNMI] will take over on the instrument side of van den Oord's work, and Jacques Claas [KNMI] will become responsible for the ground segment as of September 1. Among the OMI highlights mentioned were the observation of the eye of hurricane Katrina and the near-real-time (NRT) nitrogen dioxide (NO<sub>2</sub>) images over Europe. Levelt concluded her talk with a review of the status of OMI data products.

**Jacques Claas** [KNMI] gave an overview of OMI operations. On February 28, 2006, OMI stopped generating science data due to a folding mirror mechanism (FMM) anomaly. OMI resumed generating science data on March 3—but only Earth and dark measurements, not calibration measurements. As part of the anomaly investigation, 13 FMM tests were carried out from March 8–May 17. Although the FMM tests provided detailed information on the in-flight FMM behavior, the FMM behaved nominally during all tests and no root cause could be found for the anomaly. One possible cause—although it cannot be proven—is that instead of the usual four steps, the FMM bounced eight steps when moving to the calibration position. (This

occurred once during an on-ground test.) On June 12, OMI resumed full nominal operations generating Earth science data as well as calibration data, according to the Nominal Operations Baseline. By operating the FMM in a different way, bouncing against the calibration end-stop can be avoided. This will be implemented. Except for the FMM anomaly there have been no other instrument anomalies. OMI is thermally very stable, so no change of thermal settings is needed. New products will be developed that enable a more flexible timing of the Earth measurements during the ozone hole season.

**Marcel Dobber** [KNMI] presented an overview of OMI calibration and performance. Radiometric corrections obtained from in-flight comparisons, instead of on-ground measurements, have greatly improved OMI solar irradiance spectra.

As of February 6, ~17% of all unbinned pixels have permanently increased dark current. This can be corrected for by using a recent dark current map. Stray light parameters will be optimized as much as possible for reprocessing, but further changes in the future cannot be ruled out. A new calibration algorithm has been developed to correct for time-dependent instrument and/or calibration changes. This will enable daily updates of the dark current background images and the bad and dead pixel map. The plan is to use this algorithm for the next Level 1B (L1B) reprocessing effort planned in January 2007 leading to the *Collection 3* data set. After reprocessing, along-track stripes in the data products should be considerably reduced. Monitoring of potential optical degradation behavior using the white light source and solar spectra as well as detector degradation behavior will continue. No optical degradation has been observed thus far. Validation of Earth reflectances—including swath angle dependence—will continue. In summary, OMI performance and calibration are in good shape, although there is a calibration data gap for March-May 2006, due to the FMM anomaly investigation.

**Bert van den Oord** [KNMI] gave a summary of data processing. All data products have been provisionally released, except for L1B products and the ozone profile. Four OMI products including total ozone columns and clouds (*OMTO3*, *OMDOAO3*, *OMCLDO2*, and *OMCLDRR*) are publicly released. There were serious disk failures in 2006 and data recovery is still in progress, including a limited reprocessing effort. Operations have been nominal since the Aura launch but there were some serious hardware problems in 2005. The purchase of new storage equipment and a change in the operating system used seemed to mitigate the problems. The

team leader computing facility (TLCF) has matured and additional calibration algorithms were installed. Time-dependent (TD) calibration software is needed to correct for stripes in the OMI Level 2 products. These stripes are caused by an inadequate dark current correction with the present software. The development of TD software started in 2005. It is anticipated that the software will be ready for use in September 2006 after end-to-end-testing. This algorithm will be used to create a new collection of OMI data. The reprocessing effort will also involve an update of the *OMI 0-1b* processor. That version will include the last remaining optimization involving the stray light correction. At the meeting, an initial schedule for reprocessing was presented. Reprocessing will require substantial coordination between the calibration team, algorithm developers and the operational staff.

### June 21

Most of the second day of the meeting consisted of parallel working group meetings and workshops. Within each meeting, time was allotted for both talks and discussion. (Summaries for each of the meetings are given below.) At the end of the day, there was a core group summary, discussion, and outlook meeting. The role of the OMI Science Advisory Board (OSAB) is intended to give guidance and advice to space agencies. **P. K. Bhartia** [NASA Goddard Space Flight Center (GSFC)] is a new member of the OSAB and will replace **Ernest Hilsenrath**, who retired recently. In September, **Johanna Tamminen** [Finnish Meteorological Institute (FMI)] will return after a leave of absence.

Data policy was also discussed. Near-real-time (NRT) products will be similar to but not necessarily the same as standard products. NRT data are in principle free, although users will need to sign a data protocol agreement. NRT products can be used to make value-added products such as assimilated fields. The publication policy states that for papers that use OMI data, the OMI PI and relevant team members should be consulted to find out which people need to be added as co-authors.

### June 22

**Mark Schoeberl** [GSFC—Aura Project Scientist] gave an Aura overview talk. Most Aura validation activities have been completed. A second validation meeting was held September 11-15, 2006, in Boulder, CO—see report in this issue. However, in June 2007, a large validation campaign will take place in Costa Rica, which will include validation efforts for CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) as well as for Aura. Many new Aura datasets are being released. Papers that are to be included in the upcoming special issue of *Journal of Geophysical Research (JGR)* focusing on Aura validation

are due in March 2006. The Aura Science Team proposals for the U.S. OMI Team selection will be due around June 2007. The emphasis of the proposals should be on scientific use of the data and advanced algorithms that combined data from different instruments and platforms. Schoeberl also mentioned the *Aura Top 10* discoveries, which includes sulfur dioxide (SO<sub>2</sub>) emissions from smelters and volcanoes as determined from OMI measurements, and tropospheric ozone (O<sub>3</sub>) from combined OMI-Microwave Limb Sounder (MLS) data.

**Pieter Levelt** [KNMI] then presented the OMI project status. OMI operations are nearly flawless. There have been only four days of data loss since launch, and the previously mentioned FMM issue is now resolved. There is an extensive in-flight calibration program and L1B data will be provisionally released in June 2006, and gradually publicly released in early 2007. All data products have been provisionally released—except ozone profile and L1B data—and four data products have been publicly released. Most data products will be publicly released this year.

Several validation campaigns have been conducted. The Aura Validation Center website and OMI data processing systems performed as expected. Furthermore OMI provides near-real-time (NRT) ozone to both NOAA and the European Center for Medium-range Weather Forecasting (ECMWF), and NO<sub>2</sub> data from the KNMI website—available since January 2006. The Very Fast Delivery system has been operational since March 2006. Reprocessing for *Collection 3* will start in January 2007. The OMI ozone data have been delivered to the Intergovernmental Panel on Climate Change (IPCC). (Levelt showed observations of aerosols, NO<sub>2</sub> and tropospheric ozone from biomass burning in Australia.) Data from research instruments like OMI are not only used for climate research but also to forecast the amount of surface ultraviolet (UV) radiation, to improve weather forecasts, to forecast *chemical weather*—e.g., smog—and to support aviation control after a volcanic eruption. When people want to use public OMI data, they are advised to contact OMI Science Team representatives and read the accompanying *README* files.

The session chairs presented summaries of the working group meetings and workshops that took place on June 21.

#### *Calibration Working Group* [**Marcel Dobber**—KNMI]

In combination with the Algorithm Working Group, stray light and striping issues were discussed. The calibration team obtained feedback from Level 2 product developers on the stray light algorithm and calibration work. To mitigate stripes, algorithms can use either fixed irradiance or composite irradiance spectra. Solar diffuser features are difficult to characterize and

cannot be parameterized. Correction by calibration is therefore not feasible. Analysis of the latest linearity measurement results shows that the dynamic range has been expanded further. A preliminary comparison of radiation damage effects with other instruments shows that the radiation degradation rate for unbinned pixels normalized to the radiation environment for OMI is quite high with respect to the other instruments. These results need to be confirmed. It is difficult but necessary to separate spectral and spatial stray light. A plan has been formulated to look at asymmetrically illuminated scenes and channel overlap regions to investigate the stray light issues.

*Algorithm Working Group* [**Pepijn Veefkind**—KNMI]

Stripes are predominantly caused by irradiance problems that are produced by dark current errors, bad pixels, and diffuser features. Errors of 0.1% in irradiance measurements can result in 10% NO<sub>2</sub> errors. There are improvements in the flagging of bad pixels and daily dark current updates. Test data will be made available to product developers. After addressing the dark current problem, the composite irradiance will be optimized.

*Data Systems Working Group Meeting* [**Bert van den Oord**—KNMI]

This group had a rather technical agenda that included reports on the status of the time-dependent calibration algorithm, reprocessing plans, interfaces, and algorithm issues. By the end of 2008, all OMI products should be in *Collection 3*. Algorithm developers may be using updated algorithms for reprocessing in *Collection 3*.

*Aerosols Workshop* [**Omar Torres**—University of Maryland, Baltimore County (UMBC)]

There are two aerosol products: *OMAERO* is in development and *OMAERUV* will be publicly released shortly. For surface reflectivity, there is a problem with the blue part of the spectrum. Unfortunately there is no consistent dataset for the entire OMI spectral range. Work on OMI based surface reflectance will start after L1B reprocessing. There are 3-4 independent pieces of information on aerosols. O<sub>2</sub>-O<sub>2</sub> absorption provides one of these pieces. Cloud masking is an issue since the OMI pixel size is not ideal for aerosol retrieval. For absorption optical thickness, the cloud mask may be relaxed. Data from Polarization and Anisotropy of Reflectances for Atmospheric Sciences Coupled with Observations from Lidar (PARASOL), a member of the afternoon constellation with Aura, might be useful to help OMI improve its aerosol type determination capabilities. Early results from CALIPSO were also discussed. CALIPSO data will be used to evaluate the treatment of aerosol height determination.

*Cloud Workshop* [**Piet Stammes**—KNMI]

Comparison of Raman lidar and O<sub>2</sub>-O<sub>2</sub> cloud products is ongoing. Cloud pressures correlate poorly (0.3-0.5) for small cloud fractions but much better (0.8-0.9) for large cloud fractions. Correct cloud height assignment is essential for total ozone retrievals. The O<sub>2</sub>-O<sub>2</sub> algorithm gives generally lower cloud height than the Raman algorithm and the currently used Temperature Humidity Infrared Radiometer (THIR) climatology. Validation of cloud heights is ongoing and will include data from CloudSat/CALIPSO, the Moderate Resolution Imaging Spectroradiometer (MODIS), the Intercontinental Chemical Transport Experiment (INTEX-B), etc. For tropospheric NO<sub>2</sub> retrieval, the effective cloud fraction is an essential input parameter. The surface albedo database is also an important ingredient that should be improved in spatial resolution.

*UV Workshop* [**Aapo Tanskanen**—FMI]

The validation of the *OMUVB* algorithm showed a positive bias (0-60%) partly due to absorbing aerosols. Different absorbing aerosol corrections were discussed, but the use of aerosol absorption optical thickness was considered to be a better correction possibility. For validation of the new correction, additional low-latitude validation sites are needed.

*NO<sub>2</sub> Workshop* [**Henk Eskes**—KNMI]

There are two NO<sub>2</sub> products: operational—publicly released in September 2006—and NRT images—available since October 2005. Both products use cloud properties from the OMI O<sub>2</sub>-O<sub>2</sub> cloud product and have a filter to remove across-track biases—stripes. The OMI operational algorithm—Level 2 product—uses climatological profiles and spatial filtering to remove the stratosphere. The NRT product is a Level 4 product; data assimilation is used to estimate the stratospheric background, and the collocated NO<sub>2</sub> profiles come from model simulations. The operational product will initially use a median solar irradiance spectrum to deal with stripes, but when the time-dependent L1B algorithm becomes operational a choice will have to be made between this median spectrum and the daily irradiance measurement. Validation results were presented, in particular for the INTEX aircraft campaign and the Dutch Aerosol and Nitrogen Dioxide Experiments for validation of OMI and SCIAMACHY (DANDELIONS) campaign in the Netherlands. The first results look very promising.

*Ozone Workshop* [**Pepijn Veefkind**—KNMI]

For the OMI-Total Ozone Mapping Spectrometer (TOMS) algorithm, cloud effects are an important is-

sue, but the cloud products differ too much to currently use them in the OMI TOMS algorithm as input for the ozone trends. Furthermore, stray light effects cause a low bias at solar zenith angle (SZA) > 70°. For OMI-Differential Optical Absorption Spectroscopy (DOAS), numerous validation studies have used an old version of the product. That is unfortunate since the latest version has improved striping and better cloud data. The two products compare well on a large scale though differences occur in presence of clouds, ice, and high SZA. There is still some room for algorithm improvements. The Sodankylä Total Column Ozone Intercomparison (SAUNA) campaign in March-April 2006, focused on ozone measurements at high SZA. The OMI DOAS—Version 0.9.4 (older)—was biased high with respect to OMI TOMS and ground-based data. Possible causes are snow cover and the SZA effect. The OMI-profile software will be integrated in September 2006. There are plans to include a faster radiative transfer model.

#### *SO<sub>2</sub> Workshop* [Nick Krotkov—UMBC]

OMI volcanic SO<sub>2</sub> is ready to be released this fall and is useful in NRT for aviation warnings. The OMI boundary-layer SO<sub>2</sub> product shows a bias in the presence of clouds and is not yet finalized; therefore, vertical columns will be first produced for clear conditions. In addition, slant columns will be made available to users so they can make their own total column calculations. In the future, tropospheric SO<sub>2</sub> climatology from a chemistry/transport-model should be used for the total column calculation. Direct fitting might reduce the bias, but more research is needed. Validation of the SO<sub>2</sub> is ongoing.

#### *L2G/L3 Workshop* [Pepijn Veefkind—KNMI]

Level 2 (L2) products are data products that are on a geographical (latitude-longitude) grid. Some Level 3 (L3) products are in production or ready for production. A Level-2-gridded (L2G) product is an intermediate data product. It contains a subset of L2 products for one measurement day, ordered by location. Some L2G products are in production, others are in testing. Bert van den Oord gave a recipe of how to compute the corner points of OMI pixels. A group has been formed, with **Thomas Kurosu** [Harvard Smithsonian] as chairperson, which will work on the computation of the OMI field-of-view.

The meeting concluded with an OMI Validation Workshop. A few of the most noteworthy talks are summarized below.

**Mark Schoeberl** [GSFC—Aura Project Scientists] demonstrated an improved approach to determine tropospheric ozone column from OMI and MLS obser-

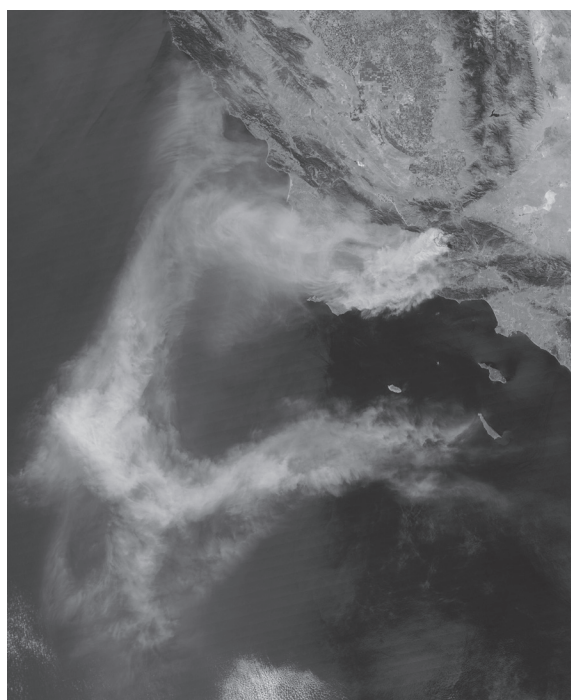
vations. The horizontal resolution of the stratospheric ozone field is improved by combining 6 days of MLS data 250 hPa – 10 hPa in a forward trajectory scheme transported to the target day.

There were several talks on the validation of OMI trace gas measurements. Comparison of tropospheric NO<sub>2</sub> measurements with ground-based measurements near Leicester, U.K. show that the weekly cycle from OMI and ground-based instruments show the expected decrease in tropospheric NO<sub>2</sub> on the weekends. Validation of OMI tropospheric NO<sub>2</sub> shows a reasonable correlation with surface measurements (0.6-0.8).

**Ellen Brinkma** [KNMI] discussed one of the Aura outreach projects. The GLOBE program shows students from secondary schools science in a practical way. The students perform aerosol measurements and provide qualitative MODIS validation. This work resulted in the first paper to be published in a peer-reviewed journal from an education and outreach project.

**Bojan Bojkov** [UMBC] gave a status report on the Aura Validation Data Center (AVDC). The AVDC provides an archive for datasets used in validation—ground-based, aircraft and other satellite datasets—and supports validation field deployment/missions. For more information, please visit: [avdc.gsfc.nasa.gov](http://avdc.gsfc.nasa.gov). ■

Northwest of Los Angeles, the Day Fire was churning out a thick, snake-like plume of smoke on September 17, 2006, when the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite passed overhead and captured this image. **Credit:** NASA image by Jeff Schmaltz, MODIS Rapid Response Team, Goddard Space Flight Center.



## Workshop on Exploring and Using Multi-angle Imaging SpectroRadiometer (MISR) Data

*Nancy Ritchey, NASA Langley Research Center, N.A.Ritchey@larc.nasa.gov*

*Charlene Welch, NASA Langley Research Center, Charlene.Welch@larc.nasa.gov*

NASA Langley Research Center's (LaRC) Atmospheric Science Data Center (ASDC) organized a one-day workshop on Exploring and Using Multi-angle Imaging SpectroRadiometer (MISR) data. The workshop was held in Adelphi, MD, at the University of Maryland University College, on September 18. Thirty-nine users from Maryland, Michigan, New York, Oregon, Hawaii, and Toronto attended. This workshop was the first to include **Eugene Clothiaux** [Pennsylvania State University (PSU)] as the main speaker and a videoconference with **David Diner** [NASA/Jet Propulsion Laboratory—*MISR Principal Investigator*].

The attendees heard presentations about the MISR instrument and research results from the various data products.

- **Nancy Ritchey** [LaRC ASDC/Science Applications International Corporation (SAIC)—*ASDC User and Data Services Representative*] spoke about MISR data access and tools,
- **Brian Rheingans** [JPL/California Institute of Technology (CalTech)] presented MISR data organization, geolocation, and data analysis. 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. MISR 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 three-dimensional models and estimation of the total amount of sunlight reflected by Earth's diverse environments.

JPL built the MISR instrument for NASA, and it was launched into sun-synchronous polar orbit aboard Terra, NASA's first Earth Observing System (EOS)

spacecraft, on December 18, 1999. MISR has continuously provided data since February 24, 2000. The data are publicly available from the NASA LaRC ASDC.

The Workshop was intended for 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 Systems (GIS)] to view and analyze the data, as well as how to obtain the products.

**Eugene Clothiaux** [PSU Department of Meteorology—*Member of the MISR Science Team*] 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 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. Clothiaux then presented MISR observational principles and an overview of the data products. A videoconference was set up to give the attendees the chance to ask MISR PI, David Diner, questions.

**Nancy A. Ritchey** [LaRC ASDC/SAIC] gave a presentation on MISR terminology, how to obtain MISR data products and information, and on using the *On-Line Visualization Tools*. Ritchey gave a demonstration of the MISR Order and Customization Tool for the participants. This tool, developed at ASDC in collaboration with JPL/MISR, enables users to order and customize data in a single interface. The new tool allows multiple consecutive and non-consecutive path and orbit searches and can sort 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 Hierarchical Data Format for the Earth Observing System (HDF-EOS) stacked-block grid or conventional grid formats. Ritchey also presented a demonstration on how some of the available tools could be used to explore the MISR data products.

**Brian Rheingans** [JPL/CalTech] presented MISR Data Analysis and Tools. Rheingans explained the Space



Oblique Mercator (SOM) projection used for MISR data products 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 Interactive Data Language (IDL) programs.

The remainder of the workshop was an interactive hands-on session for those in attendance. The partici-

pants learned how to use *mISR\_view* to open, view data values, and visualize data either as true-color or as 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](http://eosweb.larc.nasa.gov). ■

## ESIP Federation Sends Delegation to China

*Beijing, China. October 23, 2006*—The Federation of Earth Science Information Partners (ESIP Federation) recently sent representatives to a workshop in Beijing, China to assess their Chinese colleagues interest in establishing an organization comparable to the ESIP Federation in China. This meeting is a culmination of nearly two years' discussion between the ESIP Federation and Chinese representatives. Representing the ESIP Federation are current President **Chuck Hutchinson**, past Presidents **John Townsend** and **Tom Yunck**, and Executive Director **Dick Wertz**. Chinese attendees at the workshop include representatives from government, universities, non-governmental organizations, and commercial entities.

“This has the makings of a very significant meeting of the minds,” said **Chuck Hutchinson** upon accepting the invitation. “The Chinese have first-class scientists working in the Earth sciences. By working with them, the members of the ESIP Federation can help to advance the international effort aimed at establishing the Global Earth Observation System of Systems (GEOSS).”

The workshop took place October 23-25, 2006 at Beijing Normal University in China. Among the many topics being covered during the 3-day workshop are:

- ESIP Federation operations;
- ESIP Federation governance;
- data and services within China; and
- technical issues related to improving the delivery of services and products.

During its visit, the delegation also expects to meet with Chinese Minister of Science and Technology, Xu Guanhua.

According to **Thomas P. Yunck** of the Jet Propulsion Laboratory, “Environmental science and the timely dissemination of accurate environmental information are global concerns. The U.S. and China have major influences on our environment and will be critical to tomorrow's solutions. The ESIP Federation is delighted to be engaging our counterparts in China to seek those solutions in constructive partnership.”

The ESIP Federation is a 97-partner consortium of Earth science data centers, researchers, scientists, technologists, educators, and applications developers. The Federation promotes increased accessibility, interoperability and usability for Earth science data and derived products. Initiated by NASA in 1997, the Federation is sponsored by NASA and NOAA. The Foundation for Earth Science serves as the secretariat for the ESIP Federation—[www.esipfed.org](http://www.esipfed.org).

## Report from the CEOS Land Product Validation Topical Workshop on the Validation of Global Vegetation Indices and their Time Series

Jeffrey Morisette, NASA Goddard Space Flight Center, [jeff.morisette@nasa.gov](mailto:jeff.morisette@nasa.gov)

Jaime E. Nickeson, NASA Goddard Space Flight Center, [Jaime.Nickeson@gsfc.nasa.gov](mailto:Jaime.Nickeson@gsfc.nasa.gov)

Sebastien Garrigues, University of Maryland, [Sebastien.Garrigues@gsfc.nasa.gov](mailto:Sebastien.Garrigues@gsfc.nasa.gov)

Frédéric Baret, Institut National de la Recherche Agronomique, [baret@avignon.inra.fr](mailto:baret@avignon.inra.fr)

Alfredo Huete, University of Arizona, [ahuete@cals.arizona.edu](mailto:ahuete@cals.arizona.edu)

Kamel Didan, University of Arizona, [kamel@Ag.arizona.edu](mailto:kamel@Ag.arizona.edu)

Tomoaki Miura, University of Hawaii at Manoa, [tomoakim@hawaii.edu](mailto:tomoakim@hawaii.edu)

Willem van Leeuwen, University of Arizona, [leeuw@Ag.arizona.edu](mailto:leeuw@Ag.arizona.edu)

Mark Friedl, Boston University, [friedl@bu.edu](mailto:friedl@bu.edu)

A one-day workshop was held, August 7, 2006, at the University of Montana campus in Missoula, MT. It preceded the Global Vegetation Monitoring Workshop, which took place August 8-10, leveraging the turnout from that meeting to bring together both producers and users of global vegetation index (VI) time-series data. Both sessions were conducted under the auspices of the international Committee on Earth Observing Satellites (CEOS). The agenda addressed the current state of global VI records, their accuracy, and methods used to quantify the uncertainties in seasonal/phenology metrics and long-term land surface process studies. The workshop allowed researchers to review current validation strategies in the context of multi-sensor analyses to assess data continuity and proper use and interpretation of vegetation indices within both the scientific and application communities.

NASA is working with scientists in the land measurement community to define the requirements for a number of science-quality time-series data records, to be called Earth System Data Records (ESDRs). These ESDRs will be designed to meet the research and applied science needs of both NASA as well as the broader global change research community. As a first step in the process of developing these ESDRs, members of the land measurements community were tasked with leading the development of *white papers* on candidate products—visit [lcluc.umd.edu/products/Land\\_ESDR/index.asp](http://lcluc.umd.edu/products/Land_ESDR/index.asp). Two of the ESDR *white papers*, those for the *Vegetation Indices* and *Phenology* candidate products were relevant to the workshop. These *white paper* drafts provide a context for NASA/Earth Observing System (EOS) interest in the workshop. A key goal of the workshop was to contribute ideas and develop recommendations for activities supporting validation of these two ESDRs.

This report presents an overview of the meeting and summarizes some of the conclusions resulting from the presentations and discussions. Presentation materials are available at the meeting web site—[www.ntsug.umt.edu/VEGMTG/](http://www.ntsug.umt.edu/VEGMTG/), go to the link at left under VI Validation.

### Meeting Summary

**Jeff Morisette** [NASA Goddard Space Flight Center] presented an overview of the CEOS Land Product Validation Workshop objectives, including validation definitions and procedures unique to time series data.

There were five presentations on existing vegetation index time series and their validation.

- **Jeff Eidenshink** [United States Geological Survey (USGS)] discussed his agency's experience processing Advanced Very High Resolution Radiometer (AVHRR) Normalized Difference Vegetation Index (NDVI) time series since 1989.
- **Molly Brown** [Global Inventory Modeling and Mapping (GIMMS) GSFC] then followed with a discussion of their 8-km bi-monthly NDVI data set, its improvements over the Pathfinder data set, and multisensor validation efforts.
- **Eric Vermote** [University of Maryland, College Park (UMCP)] presented results from efforts of a joint NASA/University group to create a global long-term data record with continuity throughout the AVHRR, Moderate Resolution Imaging Spectroradiometer (MODIS), and Visible/Infrared Imager/Radiometer Suite (VIIRS) eras.
- **Tomoaki Miura** [University of Hawaii at Manoa] gave a talk about the sensitivities of inter-sensor NDVI relationships to bandpass, atmosphere, and land cover, and their potential cross-calibration methodologies.
- **Alfredo Huete** [University of Arizona] gave a presentation on the use of multiple VIs, including the enhanced vegetation index (EVI), as proxies for biophysical canopy processes and variables and the power of integrating these data with flux tower measurements.

Two presentations were made regarding new opportunities for VI validation.

- **Beverly Law** [Oregon State University] talked about the many validation opportunities available within tower flux networks such as AmeriFlux.
- **Brad Reed** [USGS] described efforts to create a National Phenology Network (NPN) within the U.S.

The workshop also included some presentations from users of VI data, which provided insights on how the data are being used, some of the limitations of available datasets, and future opportunities and applications.

- **Rama Nemani** [NASA Ames Research Center] and **Steve Prince** [UMCP] each gave presentations on the use of VIs in ecosystem and carbon models.
- **Paul Doraiswamy** [U.S. Department of Agriculture] and **Wim van Leeuwen** [University of Arizona] presented work on the use of VIs for agricultural and natural resource management and decision-making.
- **Fred Huemmrich** [University of Maryland, Baltimore County] and **Fred Baret** [Institut National de la Recherche Agronomique (INRA)/France] gave presentations on the use and limits of VI data in biophysical model studies.

The workshop concluded with a discussion of the presentations and opportunities to quantify the accuracy and consistency of long-term satellite VI time series.

### Conclusions and Recommendations

There were several items that participants felt should be recognized in the near term. The group wanted to emphasize that **NDVI from AVHRR is the long-term-time-series data available for global vegetation monitoring**. While important and significant improvements have been made with new sensors, and enhancement of existing and new sensors are expected, backward compatibility is required so that scientific analyses can utilize the AVHRR record. Conversely, any reprocessing of the AVHRR record should consider steps to allow forward compatibility with newer sensors and products. For example, reprocessing of AVHRR could consider other VIs—such as the Red/NIR Enhanced Vegetation Index [Huete *et al.*, 2006]—wherever possible and should include a measure of uncertainty. Overlap between sensors is desired to allow for intercomparison, checks on sensor continuity, and multi-sensor analysis. Multi-sensor analyses should recognize the difference in compatibility of absolute vs. relative values. While some biophysical modeling requires compatible VIs across sensors, some studies, such as drought warnings or the extraction of phenological metrics, may only require relative consistency.

There is a large range in sophistication and accuracy requirements across the multiple uses and users of satel-

lite vegetation indices. Also, capacities within various regions vary greatly, making specific guidance to users a challenge. However, the workshop participants reached some consensus on several research themes that could be endorsed by CEOS and pursued by its members. Specifically, research is needed to build a better understanding of:

- the issues that contaminate the VI time series—e.g., cloud cover, sensor degradation, satellite orbital drift, etc.—especially with respect to their impact on continuity);
- the effect of non-photosynthetic seasonality—e.g., soil moisture, snow cover, etc; and
- the interpretation of landscape dynamics with more than one growing season per year.

There is room for the remote sensing community familiar with VI time series to better connect with and contribute to the weather and climate modeling communities. VIs could be used to investigate how climate and human activities influence land surface phenology at a range of temporal and spatial scales. For agricultural and natural resource management applications it was felt that higher spatial resolution (i.e., < 250-m resolution) is needed.

In light of these needs, the workshop highlighted some opportunities to take advantage of the momentum from several activities designed to help better understand and utilize time-series VIs. In particular, there appears to be growing commitment from the Federal Government to support the National Phenology Network (NPN), and the USGS plans to establish a full-time, permanent executive director for NPN in early 2007. The mission of the NPN will be to facilitate collection and dissemination of phenological data to support global change research—[www.uwm.edu/Dept/Geography/npn/](http://www.uwm.edu/Dept/Geography/npn/). This network will coordinate phenological data collection from multiple national sources and establish linkages with established international networks. It will also develop protocols and methods to select and observe phenological measurements to complement existing data. The FLUXNET and AmeriFlux networks use *eddy covariance* methods to measure exchanges of carbon dioxide, water vapor, and energy between terrestrial ecosystems and the atmosphere. At present, over 200 tower sites are operating on a long-term and continuous basis—visit [www.eosdis.ornl.gov/FLUXNET/](http://www.eosdis.ornl.gov/FLUXNET/) and [public.ornl.gov/ameriflux](http://public.ornl.gov/ameriflux). These networks can provide both infrastructure and unique high temporal resolution “field” data critical to validation of remote sensing VI time series data, as well as datasets that tie those data to ecological and biophysical processes.

The discussion of the NPN and FLUXNET networks led to the question of how these networks might be

## CALIPSO Science Team Meeting Summary

*Katherine Lorentz, NASA Langley Research Center, k.e.lorentz@larc.nasa.gov*

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Team gathered recently for their first Science Team Meeting (STM) since the satellite's launch on April 28, 2006. The meeting, the group's eleventh overall science meeting, was held October 3 to 5 in Annapolis, MD.

Some of the primary goals of the STM were to:

- review the mission status and on-orbit performance;
- review algorithm status and data quality assessments;
- review validation activities to date and plans for future activities; and
- review and approve a plan for the release of initial data products.

**David Winker** [Langley Research Center (LaRC)—*CALIPSO Principal Investigator (PI)*] was pleased to report that the satellite is operating well in fine-pointing mode with the three CALIPSO science instruments in data acquisition mode. As of October 13, 2006, the primary laser on CALIPSO's lidar—Cloud-Aerosol Lidar with Orthogonal Projection (CALIOP)—has fired approximately 210 million shots on-orbit.

Winker also reported on some of the key milestones CALIPSO has achieved since launch. On May 10, the Infrared Imaging Radiometer (IIR) gathered its first data, while the Wide Field Camera (WFC) gathered its first images on May 15. On June 7 CALIOP completed its activation activities and collected its first science data—so called *first light* data. Additional checkout activities continued for the following week and the payload entered its operational science phase.

Following an intro from **Winker**, **Mike Cisewski** [LaRC] the Mission Operations Manager provided an overview of mission operations to date. Two reviews were held recently. The in-flight assessment review was held in Toulouse, France July 11-12, and the operational hand-over review was held September 7 in Newport News, VA. These reviews examined the performance of the satellite and instrument systems. Cisewski's talk was followed by a report on the status of the on-orbit lidar performance by **Bill Hunt** [SAIC/LaRC].

A major focus of this meeting was devoted to the understanding of the algorithm retrievals and the accuracy of the data products. **Mark Vaughan** [SAIC/

LaRC] gave a detailed presentation of the lidar calibration algorithm and possible changes that will be implemented in the upcoming release of the Level 1 data set. **Ralph Kuehn** [SAIC/LaRC] provided a description of the response of the lidar signal to a variety of aerosol and cloud layer features and reported on the status of the Level 2 data products.

Many validation and calibration underflights have already taken place for CALIPSO since its *first light*, and were reported by members of the science team including **Chris Hostetler** [LaRC], **Matt McGill** [GSFC], **Pierre Flamant** [Centre National de la Recherche Scientifique (CNRS)], **Anne Garnier** [CNRS], among others. Comparisons began in mid June with aircraft underflights using High Spectral Resolution Lidars (HSRL). Some of these flights were NASA-led and based out of NASA LaRC, and others were led by CNRS based out of Niamey, France. The CALIPSO-CloudSat Validation Experiment (C-CVEx), the primary calibration and validation campaign for the two missions, was held July 26-August 12 in Warner Robbins, GA. The campaign included the NASA ER-2, which flew the cloud physics lidar, and a NASA King Air B-200, with the LaRC HSRL. In August and September additional CALIPSO comparisons with other instruments were also obtained during the Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study (TexAQS/GOMACCS) campaign conducted out of Houston and Galveston, TX.

Science team members provided findings from a few preliminary studies. **Steve Ackerman** [University of Wisconsin - Madison] and **Jim Coakley** [Oregon State University] both showed comparisons of derived cloud occurrences between CALIPSO and MODIS. Comparisons between ground-based lidar observations were discussed by **Ray Hoff** [University of Maryland - Baltimore County (UMBC)] and **Kevin McCann** [UMBC].

Some key personnel changes have been made recently among the CALIPSO team: **Hal Maring** [NASA Headquarters (HQ)] is taking over from **Don Anderson** [NASA HQ] as Program Scientist; **Lou Schuster** [NASA HQ] is now the Program Executive; **Steve Volz** [NASA HQ] and **Lelia Vann** [LaRC] will now represent NASA on the CALIPSO Joint Steering Group; and **Chip Trepte** [LaRC] has been named as the Project Scientist. The team also expresses deep sadness for the loss of one science team member, **Yoram Kaufman**, [Goddard Space Flight Center—*former PI for the Moderate Resolution Imaging Spectroradiometer (MODIS)*] and a leader in the field of aerosols. Representing MODIS on the CALIPSO team in place of

Kaufman are **Lorraine Remer** [GSFC] and **Vanderlei Martins** [GSFC].

Because CALIPSO and its sister mission and launch partner, CloudSat, are part of the closely coordinated group of satellites that make up the afternoon constellation or *A-Train*, many maneuvers were required to align the two new satellites with their existing partners. From August 29 to the middle of September,

CALIPSO successfully underwent a series of A-train inclination maneuvers.

On September 12, the initial lidar browse images were released to the public, although in 532 nm and night only. Visit [www-calipso.larc.nasa.gov/products/lidar/](http://www-calipso.larc.nasa.gov/products/lidar/) to view these images. Public release of CALIPSO Level 1 data products is planned for December 2006. ■

## Report from CEOS Land Product Validation Topical Workshop

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enhanced to better engage and serve the needs of the remote sensing community. The most direct measurements would be transmittance in the photosynthetically active radiation (PAR) domain and reflectance measurements of the canopy in the red and near-infrared. Other measurements of plant growth could be associated with seasonality observed in the remote sensing VI record. Furthermore, observations of snow, rainfall, clouds, and other sky conditions would also be helpful. The discussion did not come to a consensus on a prioritization of the various measurements needed, but there was agreement that the remote sensing community should develop such a list. Other considerations included the spatial-temporal extent of the field data, regional nuances, and the land cover/land use dynamics around ground collection sites.

The participants feel that the use of VIs should converge towards their transformation into biophysical variables,

which are the only quantities that can be validated through ground measurements, and actually used directly within process models. The main conclusion was that the remote sensing community, working with time-series VI datasets, should establish and maintain collaboration and coordination with *in situ* data collection networks and users. Such mutually beneficial relationships will help to provide validation data to quantify the accuracy of the remote sensing products, while also promoting the appropriate use of the VI time series by disparate communities working in ecosystem and carbon modeling, agriculture and natural resource management, and biophysical research. CEOS, in conjunction with the Global Earth Observing System of Systems (GEOSS) should be utilized to help promote this coordination.

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## SORCE Has 4th Annual Science Team Meeting

Judith Lean, Naval Research Laboratory, Washington, DC, [jlean@ssd5.nrl.navy.mil](mailto:jlean@ssd5.nrl.navy.mil)

Peter Pilewskie, Laboratory for Atmospheric and Space Physics, University of Colorado, [pilewskie@lasp.colorado.edu](mailto:pilewskie@lasp.colorado.edu)

Tom Woods, Laboratory for Atmospheric and Space Physics, University of Colorado, [woods@lasp.colorado.edu](mailto:woods@lasp.colorado.edu)

Vanessa George, Laboratory for Atmospheric and Space Physics, University of Colorado, [vanessa.george@lasp.colorado.edu](mailto:vanessa.george@lasp.colorado.edu)

### Introduction

Approximately 60 people attended the 2006 SORCE Science Team Meeting, which was held from September 20-22 at Rosario Resort, on beautiful Orcas Island, WA. This year's meeting focused on *The Earth's Radiative Energy Budget Related to SORCE*. A summary of the meeting, including .pdf versions of the many excellent presentations, is available at [lasp.colorado.edu/sorce/2006ScienceMeeting/index.htm](http://lasp.colorado.edu/sorce/2006ScienceMeeting/index.htm). When the dates for the 2007 SORCE Science Meeting—to be held in Santa Fe, NM—are definite, the information will be posted to the SORCE Meeting website – [lasp.colorado.edu/sorce/meetings.html](http://lasp.colorado.edu/sorce/meetings.html).

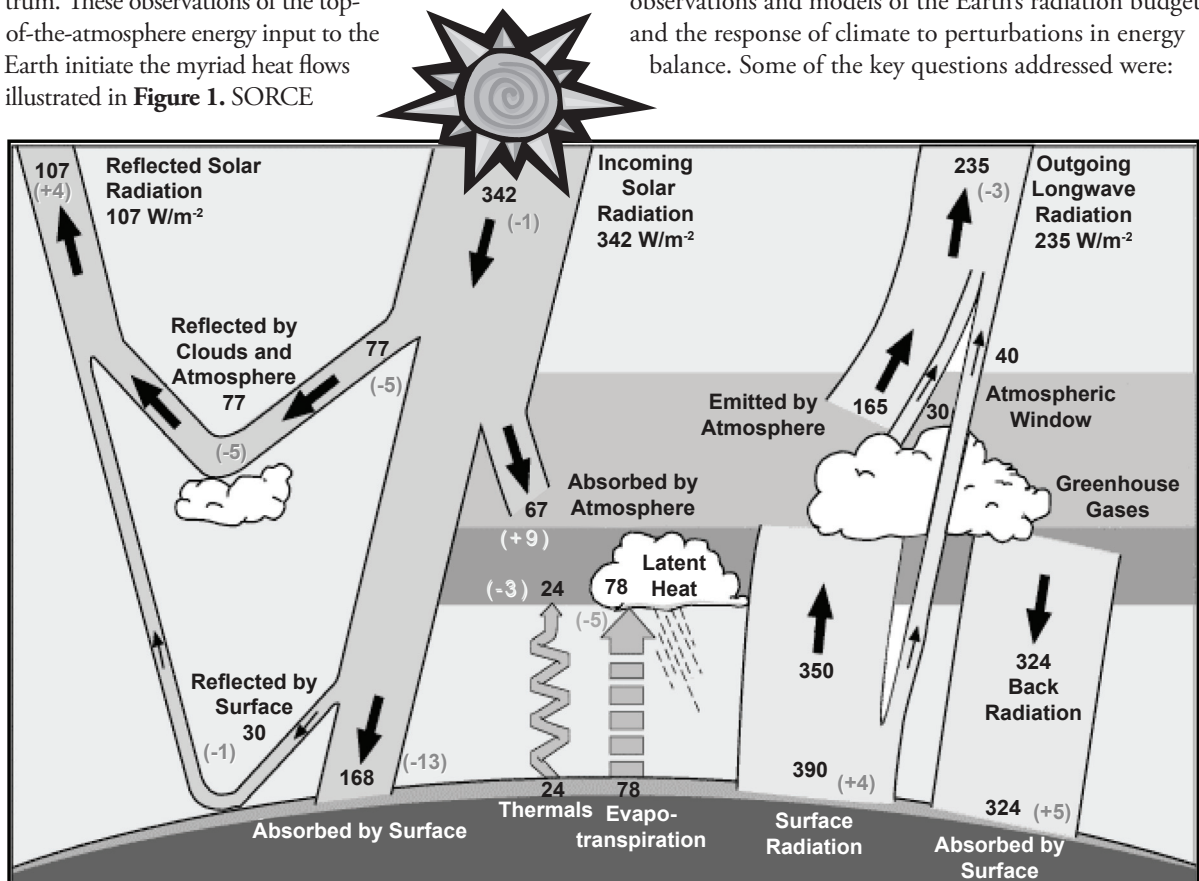
Since its launch in 2003, the Solar Radiation and Climate Experiment (SORCE) has measured solar irradiance at the top of the Earth's atmosphere with unprecedented accuracy, precision, and spectral coverage across the ultraviolet (UV), visible, and near-infrared (IR) regions of the spectrum. These observations of the top-of-the-atmosphere energy input to the Earth initiate the myriad heat flows illustrated in **Figure 1**. SORCE

Science Team meetings are convened to both highlight SORCE's unique, state-of-the-art emerging solar irradiance database and to engage the broad scientific community in wide ranging scientific issues involving solar irradiance variability, climate and the Earth's atmosphere on multiple time scales. Prior meetings—see second URL above—have addressed:

- *Physical Processes Linking Solar Radiation and Solar Variability with Global Climate Change* (Sonoma, CA, 2003);
- *Decadal Variability in the Sun and Climate* (Meredith, NH, 2004); and
- *Paleo Connections Between the Sun, Climate, and Culture* (Durango, CO, 2005).

### Meeting Goals

The goal of the 2006 meeting was the integration of the SORCE measurements of solar irradiance with observations and models of the Earth's radiation budget and the response of climate to perturbations in energy balance. Some of the key questions addressed were:



**FIGURE 1.** This schematic depiction of global energy flows in the Sun-Climate System by *Keihl and Trenberth* (1997) was shown repeatedly throughout the SORCE meeting. Quantities in parenthesis indicate changes in global heat flows in 10 years of Community Climate System Model (CCSM) research, as presented by Bill Collins in his SORCE presentation. The -1 associated with incoming solar radiation is based on the SORCE TIM results.

- *What is the present state of knowledge of the Earth's radiation budget from space, from within the atmosphere, and at the surface?*
- *What are the key radiative forcing agents, of natural and anthropogenic origin, and how have their relative influences changed in the past?*
- *What are the important feedback mechanisms for regulating Earth's climate?*
- *What is the sensitivity of climate to induced radiative forcing and over what time scales does climate respond?*

### **Session 1: *SORCE Contributions to Earth's Radiative Energy Budget***

**Tom Woods** [Laboratory for Atmosphere and Space Physics (LASP), University of Colorado (CU)—*SORCE Principal Investigator*] presented an *Overview of the SORCE Mission and its Future*.

**Greg Kopp** [LASP, CU] discussed *TSI: The Incoming Side of the Equation*. The record of total solar irradiance (TSI) measured from space is now three-decades long and has a range of approximately 0.3%. According to SORCE's Total Irradiance Monitor (TIM) the absolute value of TSI is 1361 W/m<sup>2</sup> which is ~5 W/m<sup>2</sup> lower than previously thought. A workshop held in 2005 at NIST on the accuracy of current TSI measurements discussed the potential sources for discrepancies among the various solar radiometers, and developed a plan for the first end-to-end calibration for TSI sensors to be completed under the NASA Glory mission. As Principal Investigator for Glory/TIM, Kopp emphasized that the current inaccuracies necessitate overlapping TSI observations to continue to the long-term record. This is in jeopardy because of the removal of the Total Solar Irradiance Monitor (TSIS) from the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

**Jerry Harder** [LASP, CU] presented *The Role of VIS-IR/SIM in Climate Science*, explaining how SORCE's Spectral Irradiance Monitor (SIM) is making the first ever measurements of the Sun's spectral irradiance variations in the near-UV, visible and IR spectrum, and describing simulations of variability in direct solar heating of the lower atmosphere in response to varying levels of solar irradiance measured by SIM at wavelengths longer than 200 nm.

**Bill McClintock** [LASP, CU], presented a talk on *Solar Ultraviolet Irradiance and Its Variability*. McClintock spoke on how SORCE's SOLAR Stellar Irradiance Comparison Experiment (SOLSTICE II) extends the SIM observations to 120 nm and presented composite time series utilizing observations from the SOLSTICE I and the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) instruments on the Upper Atmosphere

Research Satellite (UARS). He then discussed the morphology of solar ultraviolet irradiance variability ranging from hours to the solar cycle. SOLSTICE II resolution of 0.1 nm at 280 nm clearly resolves the emission cores of broad Fraunhofer lines.

**Martin Snow** [LASP, CU] presented *The Role of Spectral Resolution in Measuring the Solar Magnesium II Index* and showed how this higher spectral resolution enables a more precise measurement of the Magnesium II index—used widely as a proxy for solar activity in irradiance models—and that changes can be inferred on shorter timescales.

### **Session 2: *Radiative Energy Budget***

**Norman Loeb** [NASA Langley Research Center] presented a comprehensive overview of the importance of the Earth's radiation budget for climate, comparisons between the Clouds and the Earth's Radiant Energy System (CERES) and other radiation budget datasets, and the error sources in determining the global annual net top-of-the-atmosphere (TOA) radiation. In *Determination of the Earth's Radiation Budget from CERES*, Loeb pointed out that the SORCE TIM TSI value of 1361 W/m<sup>2</sup> can account for 1 W/m<sup>2</sup> out of the current 4 W/m<sup>2</sup> error in CERES net flux estimate. He also pointed out the inconsistency of CERES with trends derived from Earthshine observations.

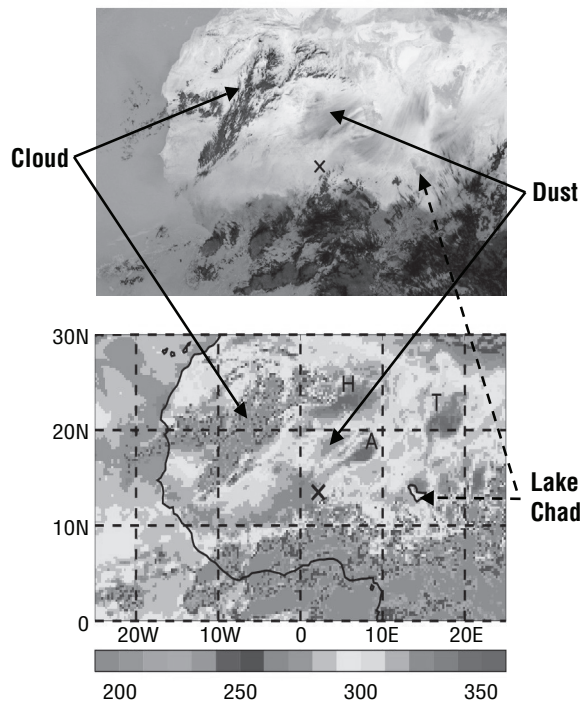
The next two talks addressed radiation budgets in the atmosphere and at the Earth's surface.

- **Peter Pilewskie** [LASP, CU] presented *An Overview of the Radiation Budget in the Lower Atmosphere*, and compared airborne observations from a number of recent experiments with remote sensing of clouds and aerosols.
- **Ellsworth Dutton** [NOAA, Boulder, CO] described the *Surface Radiation Budget Observations: Progress and Challenge*. The longer and temporally-complete but spatially-sparse ground-based data are used extensively for validation of satellite products, and both datasets are now being examined for climate related variability.

**Tom Ackerman** [Pacific Northwest National Laboratory (PNNL), Washington] presented *The Radiation Budget of an Atmospheric Column in the Tropical Western Pacific*, in which he compared modeled column surface and top-of-atmosphere emitted longwave and reflected shortwave fluxes with their measured counterparts. There was good agreement for surface fluxes and for outgoing longwave radiation but the agreement with TOA reflected radiation was considerably poorer.

Exciting new Earth radiation budget datasets are emerging from the Multiangle Imaging SpectroRadiometer

**FIGURE 2.** Geostationary Earth Radiation Budget (GERB) observations of dust over Africa, from Tony Slingo *et al.* The upper image is dust product for 1200 GMT on March 8, 2006, derived from three infrared channels of the SEVIRI imager on Meteosat-8, with centre wavelengths at 12.0, 10.8 and 8.7  $\mu\text{m}$ . The lower image is outgoing longwave radiation ( $\text{W}/\text{m}^2$ ) derived from the GERB broadband radiometer. The location of Niamey is marked by a cross on both images. It is important to note that the dust product is derived from the high resolution imager on the satellite, whereas the OLR comes from GERB. [Submitted to *Geophysical Research Letters*].



(MISR) and instruments on the Geostationary Earth Radiation Budget (GERB) spacecraft, launched respectively in 1999 and 2002.

- **Roger Davies** [The University of Auckland, New Zealand] spoke about *Constraints on the Inter-Annual Variation of Global and Regional TOA Radiation Budgets Inferred from MISR Measurements*, showing that the biggest interannual global anomalies observed by MISR that affect the top of atmosphere radiative budget appear to be those in the effective cloud height, decreasing through 2005 by about 10 m/yr, but apparently reversing the trend in the 2006 data by increasing in height.
- **Steven Dewitte** [Royal Meteorological Institute (RMI) of Belgium] presented a *Time-Space Complete Measurement of the Earth Radiation Budget*, and contrasted the high time-resolution view from geostationary orbit with high spatial coverage from low Earth-orbit satellites. GERB data, which were released for scientific use in March 2006, are providing beautiful images that allow tracking unique observations of diurnal cycle radiation and interactions of radiation, clouds, aerosols and the atmosphere.

- **Tony Slingo** [University of Reading (UoR), United Kingdom] presented *Observations of the Earth's Radiation Budget from Geostationary Orbit and from the Surface*, a captivating presentation that included a time sequence of the evolution of a dust storm in Africa—see **Figure 2**.

### Session 3: Radiative Forcings

In Session 3, meeting attendees learned about current understanding of a wide range of climate forcings from a series of informative talks covering changes in solar output, regional land use, aerosols, greenhouse gases and albedo.

*This session was dedicated to the memory of Yoram Kaufman and his contributions to understanding aerosol and cloud radiative forcing.*

**Robert Cahalan** [NASA Goddard Space Flight Center (GSFC)—*SORCE Project Scientist and the Head of Goddard's Climate and Radiation Branch*] introduced the session with a tribute to Kaufman, who had worked at the Climate and Radiation Branch at Goddard since 1979. Cahalan's tribute summarized Kaufman's professional and personal influences on the community.

As highlighted in the next four presentations, climate responses to solar cycle variability likely include direct surface heating, indirect processes involving UV radiation and the stratosphere, and modulation of internal climate system circulation patterns.

- **Judith Lean** [Naval Research Laboratory (NRL)] illustrated each of these in her talk entitled *Solar Radiative Forcing*, emphasizing that longer-term Sun-Climate associations remain ambiguous, in part due to calibration offsets among solar radiometers and in-flight sensitivity drifts, and in part because of incomplete understanding of long-term solar variability mechanisms. Current understanding points to a smaller irradiance increase since the *Maunder Minimum* than previously thought. As the *SORCE* observations demonstrate, the solar UV irradiance that creates the ozone layer varies by an order of magnitude more than the total solar irradiance.
- **Mark Weber** [University of Bremen (IUB), Germany] showed through his presentation, *Solar Variability and its Links to Ozone-Climate Interaction*, that the direct radiation impact on lower stratospheric ozone—as represented by total ozone—is rather small, so solar irradiance variability must alter ozone via dynamical feedbacks. Using satellite total ozone data starting in 1979—including data from the Solar Backscatter Ultraviolet (SBUV) instrument, Total Ozone Mapping Spectrometer (TOMS), and Global Ozone Monitoring Experiment (GOME)—he further showed that the recent increase in ozone



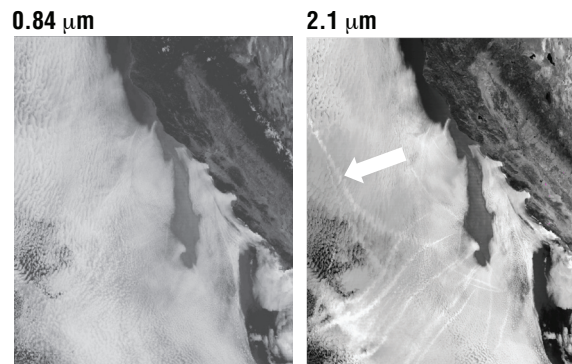
in both hemispheres has a rather minor contribution from changing halogen levels, but is in large part related to the increasing strength of the Brewer-Dobson circulation governing ozone transport into high latitudes and the rise of solar cycle 23.

- **Roger Pielke Sr.** [CIRES, CU] articulated the need to quantify climate forcings on regional and local scales—to date they are usually only quantified at the global scale. Pielke spoke on *Regional and Global Climate Forcings – The Need to Move Beyond a Focus of the Radiative Forcing of the Well-Mixed Greenhouse Gases*, emphasizing that the Intergovernmental Panel on Climate Change (IPCC) Reports, the Climate Change Science Program (CCSP) Report on surface and tropospheric temperature trends, and the U.S. National Assessment have overstated the role of the radiative effect of the anthropogenic increase of carbon dioxide (CO<sub>2</sub>) relative to the role of other human climate forcings (e.g., land use changes) on global warming, and more generally, on climate variability and change. Atmosphere-ocean general circulation models (AOGCMs) are part of the current climate assessment by the Intergovernmental Panel on IPCC and there are substantial discrepancies among the AOGCMs in the ensemble and between the AOGCMs and reference line-by-line codes.
- **Bill Collins** [National Center for Atmospheric Research (NCAR)] presented an evaluation of *Radiative Forcing by Greenhouse Gases and its Representation in Global Models*. In some cases the differences occur because the AOGCMs neglect particular absorbers, while in others it is due to the methods for modeling the radiative processes. These differences have important implications for interpreting variations in forcing and response across the multi-model ensemble of AOGCM simulations assembled for the IPCC fourth assessment report (AR4). Collins presented promising new mathematical methods for improving the accuracy of the radiative parameterizations in global models. Collins summarized by presenting the *Kiehl and Trenberth* energy budget diagram—see **Figure 1**—along with updated changes in global heat flow quantities based upon 10 years of Community Climate System Model (CCSM) research.

There were also three talks focusing on studies of the impact of aerosols on Earth's climate system.

- **Brian Cairns** [Goddard Institute for Space Studies (GISS), Columbia University] spoke on *Using Models and Measurements to Understand and Constrain the Direct Effect of Aerosols on Climate*, and explained that one of the most significant but least certain forcings is that caused by aerosols, and the reasons are due to variable aerosol composition leading to either heating or cooling, their relative short lifetimes, and the highly heterogeneous global distri-

**FIGURE 3.** Jim Coakley used ship tracks (arrow) to better understand aerosol indirect effects. This image is 1-km Aqua/Moderate Resolution Imaging Spectroradiometer (MODIS) data acquired 1915 UTC on June 11, 2002. Comparisons are made under conditions such that the only difference between affected clouds and nearby pristine clouds is the additional particle loading.



bution. Cairns discussed how new remote sensing measurements using airborne and spaceborne polarimetry, planned for the Glory mission, can be used to reduce the uncertainty in the radiative forcing of climate by aerosols, as well as reduce uncertainties in the processes that must be modeled in order to predict the future forcing of climate by aerosols.

- **Jim Coakley** [Oregon State University (OSU)] demonstrated that understanding aerosols effects on clouds is perhaps the most challenging part of determining how aerosols are affecting the climate. In *The Aerosol Indirect Effect*, Coakley used observations of the response of marine stratocumulus to aerosols generated by ships off the west coast of the U.S. to estimate the aerosol indirect radiative effect—see **Figure 3**. He showed that by increasing cloud cover fraction, the increase in particulate pollution causes radiative forcing comparable to that for the changes in droplet numbers and radii. There is additional uncertainty in cloud radiative forcing in regions where sea-salt aerosols (SSA) are the dominant aerosol species.
- **Antony Clarke** [University of Hawaii (UH)] spoke on *An Ultrafine Sea-Salt Flux from Breaking Waves: Implications for CCN in the Remote Marine Atmosphere*. Clarke reported measurements showing that SSAs extend to sizes an order of magnitude smaller than previous published values. When newly determined fluxes of *ultrafine* SSA are applied to oceanic whitecaps, strong regional and temporal differences become apparent in the open-ocean surface number flux. The introduction of an ultrafine component of SSA into the Goddard Institute for Space Studies (GISS II)-prime general circulation model increased calculated cloud condensation nuclei (CCN) over most oceanic regions by up to 10% relative to the SSA source functions without an ultrafine component.

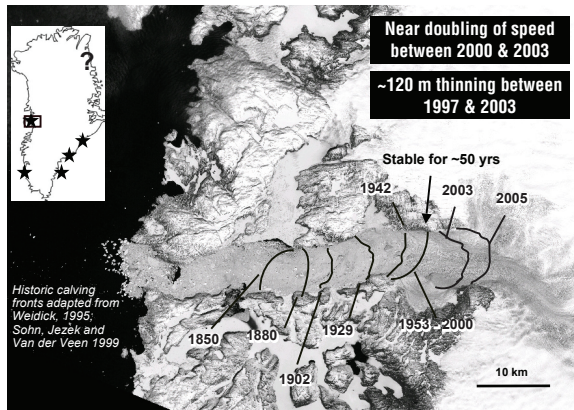


Figure 4. Retreat of the Jakobshavn Ice Stream (Ken Jezek).

**Steven Lloyd** [The Johns Hopkins University (JHU)] concluded Session 3 and revisited the issue of Earth radiation budget discrepancies between CERES and Earthshine. Lloyd described *A 27-Year Composite Dataset of Global UV Effective Reflectivity from the TOMS and SBUV(12) Satellite Instruments* that provides insight into the issue of long-term changes in the effective albedo of the Earth (i.e., global dimming) and climate feedback mechanisms (i.e., global warming).

#### Session 4: Climate Responses and Feedbacks

**K. K. Tung** [University of Washington (UW)] presented *Climate Sensitivity Inferred from Atmosphere's Response to the Radiative Forcing of the 11-Year Solar Cycle, including Feedbacks*, and explained that uncertainties in model predictions of equilibrium global mean warming due to a doubling of atmospheric  $\text{CO}_2$  are due to differing magnitudes of the feedback processes, including water-vapor, ice-albedo, and clouds. All of these factors taken together magnify the climate response by a factor of  $\sim 1$  to 3. Using recent instrumental records to estimate climate sensitivity, he established a *largest lower bound* in response to a doubling of  $\text{CO}_2$ . A solar cycle signal with a globally averaged surface warming of  $0.17 \pm 0.04$  K for each  $\text{W}/\text{m}^2$  increase in total solar irradiance translates into  $0.80 \pm 0.19$  K per  $\text{W}/\text{m}^2$  of direct radiative forcing, about the same as the Vostok ice core result but with smaller uncertainties. These results rule out models predictions of equilibrium warming less than 2.3 K and exclude the possibility of no positive climate feedback. Incoming solar radiation is a dominant process of the upper ocean heat budget, except in relatively narrow regions with strong upwelling currents in the upper ocean.

**David Halpern** [NASA Headquarters (HQ)] spoke on *Ocean-Atmosphere Interfaces in Climate*, and explained that buoy measurements of incident shortwave radiation are essential in combination with satellite measurements of incident shortwave radiation in the development of radiation fields at the surface over the global

ocean. Important, complex and possible non-linear climate processes occur as a result of air-sea interactions. Examples include:

- enhanced global ocean absorption of anthropogenic longwave radiation due to increasing amounts of atmospheric greenhouse gases, producing a rise in global sea level; and
- El Niño and La Niña links to redistributions of heat in the upper ocean along the Pacific equator, producing a redistribution of heating in the atmosphere.

**Robert Cahalan** [NASA GSFC] spoke on *Three-Dimensional Cloud Properties and Climate*, in which he discussed the major international effort toward advancing computational radiative transfer tools documented in the *Intercomparison of 3 Dimensional Radiation Codes (I3RC)* and he addressed a number of important questions, such as:

- How do the physical and radiative properties of clouds depend on resolution?
- How do cloud scaling or fractal properties impact Earth's climate, or does it matter?
- How might cloud scaling properties help improve the measurement and modeling of clouds?
- What breakthroughs might be expected in cloud research in the next decade?

**Ken Jezek** [The Ohio State University (OSU)] documented the crucial role that Earth's ice and snow-covered regions play in regulating the Earth's climate system. In his presentation, *Recent Changes in Earth's Cryosphere*, Jezek showed how the polar ice sheets, sea ice, seasonal snow cover, glaciers, permafrost, and ice-atmosphere interactions are changing—see **Figure 4**. A variety of space-based observations—e.g., from the Moderate Resolution Imaging Spectroradiometer (MODIS), Interferometric Synthetic Aperture Radar (InSAR), and the Ice, Cloud, and Land Elevation Satellite (ICESat)—provide dramatic evidence of recent changes. On longer time scales, there is a world wide retreat of glaciers and a century-long permafrost warming. Impacts of cryosphere variations are likely widespread, and may include global sea level rise and involve biological processes. Repeated continental scale observations of the polar regions are needed to capture and compare spatial and temporal variations of the interactions of ice, ocean, atmosphere and land. Future challenges include determining the long-term impacts of a changing cryosphere on other components of the Earth system, as well as predicting the responses of snow, glaciers, ice sheets, permafrost, and sea ice to changing climate.

As the next two talks described, simulations with atmospheric and climate models are key tools for assessing possible mechanisms of climate change.

- **Steve Rumbold** [UoR, United Kingdom] described simulations of the *Effect of the 11-Year Solar Cycle on Stratospheric Temperatures*, using a narrow band model to obtain radiative heating rates and a fixed dynamical heating model to assess the resultant temperature change in the stratosphere between solar minimum and maximum. The key results are a solar signal in annual mean temperature (solar maximum minus solar minimum) of  $-1.8$  K at the equatorial stratopause, a lower stratosphere sub-tropical signal ( $-0.5$  K in the Northern Hemisphere) and an equatorial middle stratosphere minimum response, which is in agreement with some previous studies.
- **Jose Rial** [University of North Carolina (UNC)] gave a presentation entitled *Solar Forcing and Abrupt Climate Change over the Last 100,000 Years*, where he compared ice core data of the last 100,000 years with climate models of low and intermediate complexity, to show that the source of the abrupt Dansgaard-Oeschger oscillations is a form of convective instability of the thermohaline circulation (THC). Rial suggested that the abruptness of these oscillations is controlled by the response of the sea ice, whose rapid advances and retreats, triggered by the switching THC, are accelerated by ice-albedo and greenhouse gas (GHGs) feedbacks. The modeling results indicate that solar forcing organizes the free oscillations to form the characteristic pattern of abrupt climate change over the last ice age.

**Dominique Crommelynck** [Royal Meteorological Institute (RMI) of Belgium] presented *The Observation of the Earth Radiation Budget: A Set of Challenges*, and identified problems associated with high spatiotemporal, spectral, and angular variability of the target, the imperfect spectral integration of the measured radiation, and the conversion of filtered radiances to total irradiance.

**E. J. Zita** [The Evergreen St. College, Olympia, Washington] is a science teacher who regularly attends SORCE-related meetings. Zita presented *Earth's Energy Balance: Climate Change Workshops*, and described the *Fire and Water* program at her college, where a solar physicist and a biological oceanographer will co-teach an integrated undergraduate program in Fall 2006. Students will analyze questions such as:

- What would Earth's equilibrium temperature be without a greenhouse effect?
- What is the effect of clouds on the atmospheric radiation budget?
- How does inclusion of ocean and ice albedo change this equilibrium?
- How do variables such as plankton and temperature contribute to changes in albedo?

In addition to providing meeting attendees with an instructive glimpse into classroom teaching related to SORCE, she plans to include data and methods from the SORCE meeting in some more advanced workshops.

### Conclusion

**Tom Woods** [LASP, CU] concluded the highly enjoyable 4<sup>th</sup> Annual SORCE Meeting with a summary of the excellent presentations and engaging science discussions, and thanked Vanessa George for the beautiful vistas, fine social events, and whale sightings enjoyed during the past two and a half days.

### Poster Reception

During the Poster Reception, attendees had an opportunity to peruse the contributed posters while enjoying drinks, appetizers and social interactions. The presenters were **Antony Clarke** [UH], **Matt DeLand** [SSAI], **Frank Eparvier** [LASP, CU], **Juan Fontenla** [LASP, CU], **Claus Fröhlich** [Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, Switzerland], **Barry Knapp** [LASP, CU], **Greg Kopp** [LASP, CU], **Robert Kurucz**, [Harvard-Smithsonian Center for Astrophysics, Massachusetts], **Jeff Morrill** [NRL], **Julia Saba** [Lockheed Martin, ATC Solar & Astrophysics Lab, Maryland], **Martin Snow** [LASP, CU], **Mark Weber** [UB, Germany], **Guoyong Wen** [NASA GEST GSFC]. ■



Gary Rottman entertained the SORCE Science Dinner attendees with his tales of the Earth/Sun/Science funding connection.

## SORCE Team Organizes Solar Spectral Irradiance Intercomparison Workshop

*Martin Snow, Laboratory for Atmospheric and Space Physics, University of Colorado, snow@lasp.colorado.edu*

*Jerald Harder, Laboratory for Atmospheric and Space Physics, University of Colorado, harder@lasp.colorado.edu*

*Bill McClintock, Laboratory for Atmospheric and Space Physics, University of Colorado, mcclintock@lasp.colorado.edu*

*Tom Woods, Laboratory for Atmospheric and Space Physics, University of Colorado, woods@lasp.colorado.edu*

### Overview

A one-day workshop was held on September 19, 2006, in association with the Solar Radiation and Climate Experiment (SORCE) Science Team Meeting, to discuss measurements of the solar spectral irradiance (SSI) from different instruments. The heart of the conversation was the comparison of the two spectrometers on SORCE to other observations. The SORCE measurements are from the SOLar-STellar Irradiance Comparison Experiment (SOLSTICE) and the Solar Irradiance Monitor (SIM). These two instruments in combination measure the solar irradiance from 115 nm to 2.7  $\mu\text{m}$ . Variation in the solar irradiance over this wavelength range influences a wide range of processes from the upper atmosphere to the whole climate system. The long-term data record of the solar radiative output is made of a composite of measurements from a variety of sensors, and understanding the instrumental effects in each dataset is crucial to assembling a meaningful composite time series.

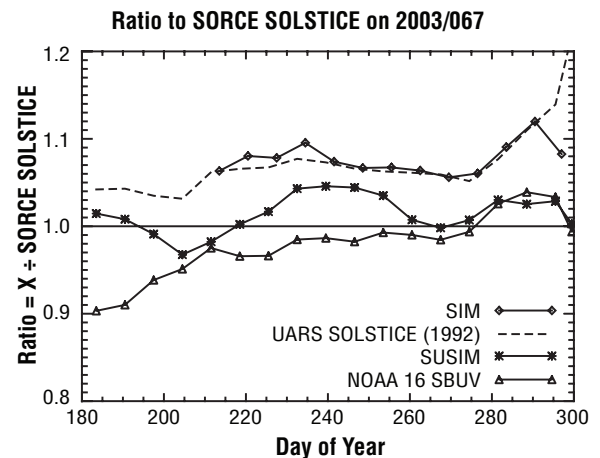
The morning session of the workshop covered the ultraviolet (UV) portion of the spectrum, while the afternoon was devoted to the visible and infrared (IR).

### Ultraviolet Session

There were four presentations in the morning session, all concerned with measurements of SSI from  $\sim 115$ –300 nm. This region of the solar spectrum is highly variable on both short and long time scales. Radiation from these wavelengths is predominately absorbed by molecular oxygen and ozone in the upper atmosphere and is the major driver of chemical and dynamical processes in the thermosphere, mesosphere, and stratosphere.

**Matt Deland** [Science Systems and Applications Inc. (SSAI)/Goddard Space Flight Center] discussed his work to create a composite of solar UV measurements from 1978 to the present. He showed some of the challenges of this undertaking, which range from gaps in the data record—not enough data—to conflicting simultaneous measurements—too much data—and he reviewed the progress he has made in assembling a unified composite. Deland also noted that greater involvement from the SOLSTICE and Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) instrument scientists would aid in the construction of this reference spectrum.

**FIGURE 1:** Preliminary analysis of calibration differences in the middle ultraviolet. The four curves shown in this figure are the ratio of measurements from SORCE SIM, UARS SOLSTICE, UARS SUSIM, and NOAA 16 SBUV to SORCE SOLSTICE. The published uncertainties of each instrument are on the order of a few percent, so agreement at this level is to be expected.



**Linton Floyd** [Interferometrics, Inc.] discussed the responsivity calibration of the SUSIM on the Upper Atmosphere Research Satellite (UARS). This instrument measured SSI between 108–412 nm from September 1991 through August 2005. Changes in responsivity were tracked with onboard deuterium lamps and duty cycling of redundant optical elements.

**Martin Snow** [Laboratory for Atmospheric and Space Physics (LASP), University of Colorado] gave a presentation on the calibration of SOLSTICE instruments on both the UARS and SORCE platforms, as well as a comparison of SOLSTICE and SUSIM time series. Long-term changes in responsivity of SOLSTICE are tracked via comparison with stellar irradiances, but the UARS instrument lost its capability to routinely observe stars at the end of 1999. Both Snow and Floyd noted that an important source of uncertainty in tracking degradation is the different field-of-view for the Sun and calibration sources (lamps or stars). The absolute irradiance measured by SORCE SOLSTICE is in agreement with the other UV SSI measurements at the 1-standard-deviation ( $\sigma$ ) level—see **Figure 1**.

**Francis Eparvier** [LASP, University of Colorado] gave a summary of how SOLSTICE and SUSIM data are used in analysis of the Solar Extreme Ultraviolet (EUV) Experiment (SEE) on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. The SEE team uses a combination of SUSIM, SORCE SOL-

STICE, and rocket underflights to measure the degradation rate of their instrument.

### Ultraviolet Conclusions

In addition to the ultimate goal of having consistent composite time series dating back to 1978, it was determined that a set of UV reference spectra should be produced in the near future. Two spectra, one for *solar maximum* and one for *solar minimum* levels, have often been used by climate modelers in the past, but more are needed. A solar proxy measurement such as the *Mg II index* or *F10.7* radio flux could then set the scaling between them for any given date. While this approximation is useful for long-term climate studies, we encourage the atmospheric community to directly use the more accurate measurements, such as from SORCE.

The UV solar irradiance presenters also had some very fruitful discussions about technical aspects of each mission's data products. Small details such as the time of day for measurements and wavelength binning were examined and noted for further analysis, as well as the larger issues of long-term trends and calibration offsets.

It was recognized that atmospheric and climate modelers are currently upgrading some of their radiative transfer modules such as the transition to a new version of the Community Atmospheric Model—from CAM3 to CAM4—and that the time is ripe for encouraging use of more detailed solar measurements.

**Peter Pilewskie** [LASP, University of Colorado] presented a summary of a workshop that was held in Boulder, CO in August 2006. At that workshop, the SORCE scientists met with climate modelers from the National Center for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), Naval Research Laboratory (NRL), Atmospheric and Environmental Research, Inc. (AER), NASA/Jet Propulsion Laboratory (JPL), and the University of Colorado, to share information about what measurements were available from the instruments as well as what types of SSI inputs for the models were desired—a summary of this meeting appears in the September/October 2006 issue of *The Earth Observer*. There is a compelling need to include realistic solar variability in these models, and continued work with the modeling community is necessary to find workable solutions to include these measured datasets in the current climate modeling efforts.

### Visible and Infrared Session

**Gerard Thuillier** [Service d'Aéronomie du CNRS (Centre national de la recherche scientifique), France] gave a presentation that described his SOLar SPECtral Irradiance (SOLSPEC) composite spectrum. (This bridged the morning discussion of the UV with the topic of the afternoon, the visible and infrared, since his composite goes from

the X-ray region to the IR.) The spectrum is composed of rocket measurements below 120 nm, UARS SOLSTICE and SUSIM data in the far ultraviolet (120–200 nm), a combination of UARS and Atmospheric Laboratory for Applications and Science (ATLAS) measurements in the middle ultraviolet and near UV (200–400 nm), SOLSPEC measurements from ATLAS (400–870 nm), and SOLSPEC measurements from the EUROpean Retrieval CARRIER (EURECA) (870–2400 nm). These measurements combine to produce two reference spectra for different levels of solar activity.

**Claus Fröhlich** [Physikalisch-Meteorologisches Observatorium Davos, Switzerland] presented a comparison of the World Radiation Center (WRC)85 spectrum with SOLSPEC. Like the SOLSPEC spectrum described above, the WRC85 spectrum is a composite of different observations. Four spectra are combined and scaled to produce an integrated irradiance of 1367 W/m<sup>2</sup>. Comparisons with the SOLSPEC spectrum are within the stated uncertainties in the visible, but are larger than the published uncertainties in the UV and IR. These differences are on the order of 10% at 200 nm and at 2000 nm.

Fröhlich also talked about observations from the sun photometer (SPM) filter-radiometers on the Variability of Solar Irradiance and Gravity Oscillations (VIRGO) instrument that flies on the Solar and Heliospheric Observatory (SOHO) that measure solar irradiance at 402, 500, and 862 nm respectively. After correction for degradation, time series data from these three photometer channels could be compared to SIM.

**Mark Weber** [University of Bremen, Germany] showed the spectrum from the UV through the near infra-red measured from the Global Ozone Monitoring Experiment (GOME) and SCanning Imaging Absorption spectroMeter for Atmospheric ChartographY (SCHIAMACHY.) This instrument measures the reflected sunlight relative to the solar input, so an absolutely calibrated measurement of SSI is not required, and there is only a limited capability for in-flight degradation measurements. Even so, the observations agree with other spectra discussed at this workshop at the 5% level. The combined GOME and SCHIAMACHY mission provide a measurement of solar spectral variability throughout the 240–790 nm region over one full solar cycle (1995 to present) and SCHIAMACHY has been providing additional information in the 790–2400 nm range since its launch in 2002.

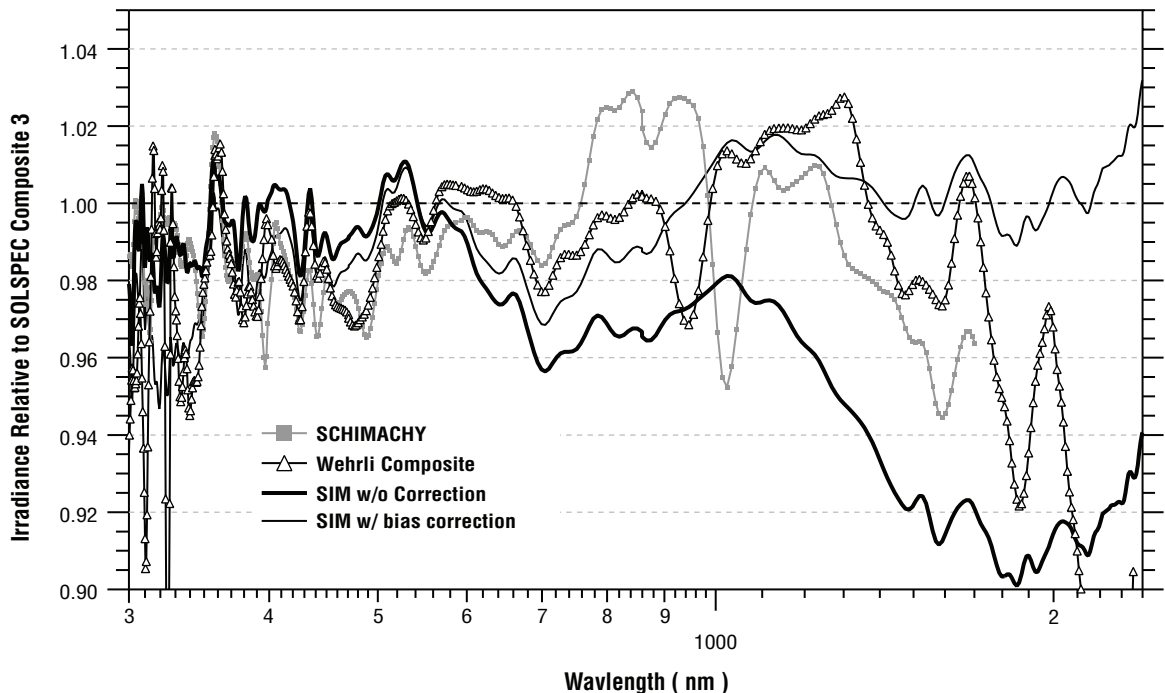
**Jerry Harder** [LASP, University of Colorado] discussed the in-flight, long-term precision and absolute calibration of the SIM instrument. Harder's presentation showed how measurements of prism degradation and comparisons of the two independent spectrometers of SIM are used to correct for long-term drifts of the instrument. **Figure 2** shows the ratios between SIM, SCHIAMACHY, and the WRC85 composite with SOLSPEC composite 3 at the SIM resolu-

tion in the 300-2400 nm range. The plot shows two curves for SIM: one shows the current long wavelength electrical substitution radiometer (ESR) efficiency correction based on comparison with SOLSPEC, and the other shows data measured without this correction. The plan is to replace this bias correction with measurements at the National Institutes of Standards and Technology's (NIST) Spectral Irradiance and Radiance Calibrations with Uniform Sources (SIRCUS) facility using the SIM ESR flight spare. The plot shows that the four measurements agree to about the 2-4% level in the visible part of the spectrum (300-1000 nm) with larger deviations in the infrared. More work and comparisons must be done to understand these differences.

**Joe Rice** [NIST] presented a progress report on the calibration of the SIM flight spare ESR detector and engineering model spectrometer using the NIST SIRCUS facility. The laser system provided valuable characterization of the SIM slit instrument profile and scattered light response of the instrument function. Most importantly, the measurement campaign provided promising preliminary information on the calibration of the ESR's wavelength responsivity function. A second campaign is planned to repeat these measurements to extend the spectrometer's slit scatter function measurements into the UV and IR, and to repeat the ESR calibration with closer wavelength sampling, extend the measurement further in the UV and IR, and establish better the uncertainty of the measurement. **Figure 3** shows the preliminary results from the ESR calibration study. The solid curve is the correction factor used in **Figure 2**. These new results show that the measured efficiency of the ESR in the IR matches the empirical correction factor that has been previously applied to SIM data.

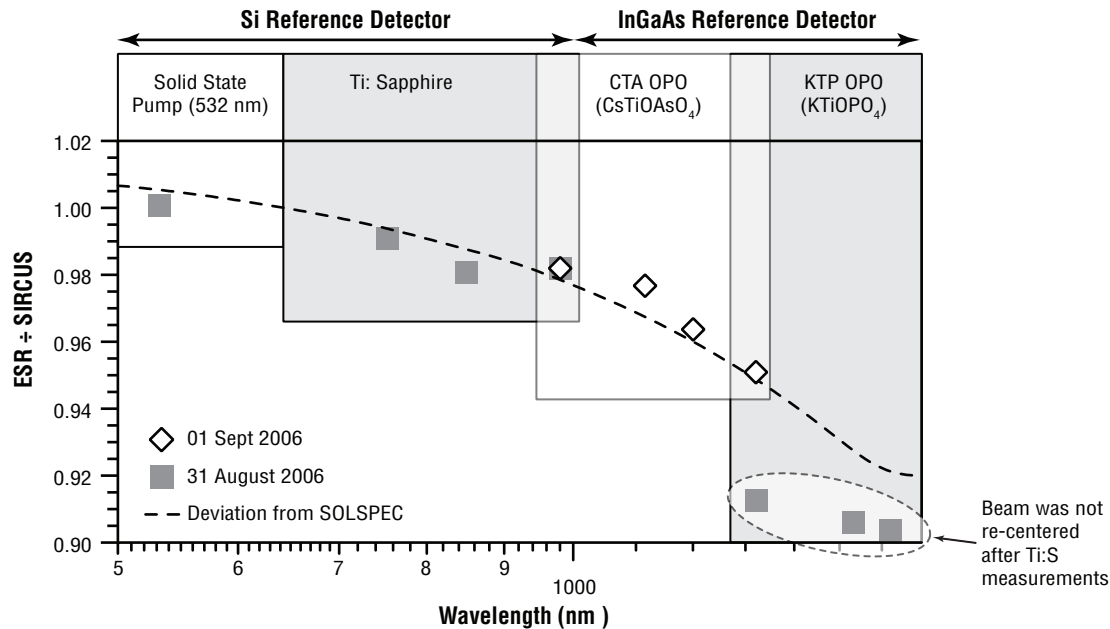
**Geoffrey Toon** [JPL] presented a summary of the state-of-the-art of the absolute solar spectrum in the IR (2-16  $\mu\text{m}$  or 600-5000/cm) with emphasis on results from the balloon-based *MkIV* and shuttle-based Atmospheric Trace Molecule Spectroscopy (ATMOS) interferometers. There has been less progress on parameterizing the solar continuum irradiance in the IR than there has been in the UV and visible spectral regions. IR instruments with high radiometric accuracy tend to have lower spectral resolution and vice versa. To date, none of the active ground-based, balloon-borne or space-based instruments have a rigorous absolute calibration; all of these instruments are used for detection of atmospheric trace gases, so this calibration effort has not been actively pursued. The best estimate of the solar continuum irradiance will come from a combination of ground, balloon, and space-based instruments. The *MkIV* interferometer has been calibrated against a commercial 1000° C blackbody, but the direct Sun is much brighter than a 1000° C blackbody so effects due to detector non-linearity and gain changes become important error sources. The pursuit of this absolute calibration will be important for future missions.

**Robert Kurucz** [Harvard-Smithsonian Center for Astrophysics] discussed his analysis of combining ground-based high spectral solar observations from Kitt Peak National Observatory in Arizona with both modeled and measured spectra. Kurucz analyzed the Kitt Peak data set to remove telluric contributions to leave only spectral structures associated with the sun. This residual spectrum can then be combined either with a calculated or semi-empirical solar model (for this meeting, the Kurucz ASUN model was used) to give the absolute spectrum, or the residual spectrum can be



**FIGURE 2:** Comparison of visible and infrared spectra to the SOLSPEC composite for the spectra used in this workshop. Each spectrum has been convolved with the SIM instrument function for comparison. Two curves are shown for SIM, one with the current long wavelength ESR efficiency correction, and the other without. **Figure 3** shows laboratory measurements of this correction factor.

**FIGURE 3:** The efficiency of the SIM ESR measured at SIRCUS. The symbols indicate measurements from the flight spare ESR on the given dates. The dashed curve is the empirically determined correction factor needed to bring the SIM spectrum into agreement with SOLSPEC. The SIRCUS measurements confirm this correction factor with laboratory measurements.



smoothed and broadened to match the resolution of lower resolution instruments that have a good absolute calibration, such as SIM and SOLSPEC. A study of this kind is very useful in understanding the absolute solar continuum level and evaluating measured spectra.

**Juan Fontenla** [LASP, University of Colorado] described the Solar Radiation Physical Model (SRPM) that he developed at LASP. Fontenla's research integrates the results of measured solar spectra (such as SIM, SOLSTICE, SOLSPEC, and SUSIM) with detailed semi-empirical models of the solar atmosphere. The goals of SRPM are to: 1) provide a high resolution solar reference spectrum throughout the UV/Visible/IR spectral regions that is representative of the quiet Sun; 2) provide a variability spectrum at full-resolution for any observed distribution of solar activity for any given mask image of observed solar activity; and 3) understand sources of solar spectral variability at full-resolution. One of the new findings from this study suggests that the temperature minimum in the solar atmosphere is about 400 km higher than previously assumed, and this change produces better agreement with observed spectra.

The afternoon session was capped with discussion on two future missions.

**Gerard Thuillier** gave a presentation on SOLSPEC-ISS that will be deployed on the International Space Station in late 2007. SOLSPEC-ISS consists of three double spectrometer systems that cover the 180-3000 nm range and lamps for in-flight photometric and wavelength calibration.

**Hartmut Boesch** [JPL] described the Orbiting Carbon Observatory (OCO) scheduled for launch in September

2008 with a two-year lifetime. OCO will provide global, space-based observations of atmospheric CO<sub>2</sub> with the needed precision, resolution, and coverage to monitor sources and sinks of this increasingly important atmospheric trace gas. The measurement requires an empirical solar reference spectrum algorithm that must be validated with calibrated solar irradiance spectra from measurements and models such as those discussed in this workshop.

### Visible and Infrared Conclusions

The following items best summarize the needs, plans, and actions for visible and infrared measurements:

- Further and more detailed comparisons among these instruments must be performed and published. For instance comparisons of the absolute scale (accuracy) and solar variability of SIM, SCHIAMACHY, SOLSPEC, and VIRGO SPM are planned and needed. Future comparison activities will continue with launch of SOLSPEC-ISS and the continuing SORCE and SCHIAMACHY missions.
- The greatest uncertainties in agreement between the instruments are in the IR. Activities like the SIRCUS/SIM ESR calibration are needed to refine the on-orbit SIM calibration parameters. Future missions like OCO require good calibration of the solar continuum in the IR, and other space missions require good calibration further into the IR past 3000 nm. These measurements can be aided and extended by inclusion of solar model calculations such as from SRPM and ASUN. ■

## NASA and NOAA Announce Ozone Hole is a Double Record Breaker

*Rob Gutro, NASA Goddard Space Flight Center, Robert.J.Gutro@nasa.gov*

NASA and National Oceanic and Atmospheric Administration (NOAA) scientists report this year's ozone hole in the polar region of the Southern Hemisphere has broken records for area and depth.

The ozone layer acts to protect life on Earth by blocking harmful ultraviolet rays from the sun. The *ozone hole* is a severe depletion of the ozone layer high above Antarctica. It is primarily caused by human-produced compounds that release chlorine and bromine gases into the stratosphere.

"From September 21 to 30, the average area of the ozone hole was the largest ever observed, at 10.6 million square miles," said **Paul Newman**, atmospheric scientist at NASA's Goddard Space Flight Center, Greenbelt, MD. If the stratospheric weather conditions had been normal, the ozone hole would be expected to reach a size of about 8.9 to 9.3 million mi<sup>2</sup>, about the surface area of North America.

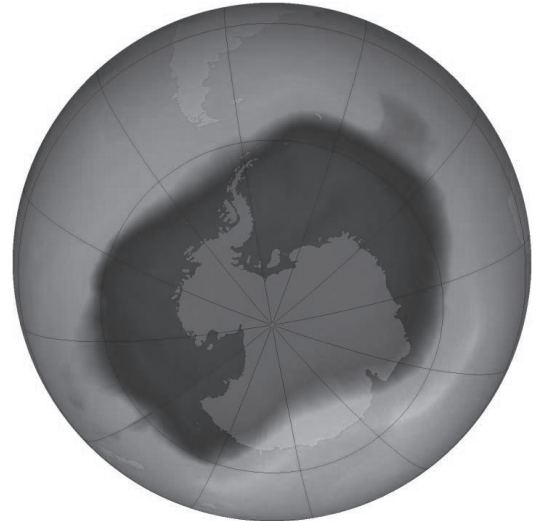
The Ozone Monitoring Instrument (OMI) on NASA's Aura satellite measures the total amount of ozone from the ground to the upper atmosphere over the entire Antarctic continent. This instrument observed a low value of 85 Dobson Units (DU) on October 8, in a region over the East Antarctic ice sheet. Dobson Units are a measure of ozone amounts above a fixed point in the atmosphere. OMI was developed by the Netherlands' Agency for Aerospace Programs, Delft, The Netherlands, and the Finnish Meteorological Institute, Helsinki, Finland.

Scientists from NOAA's Earth System Research Laboratory in Boulder, CO, use balloon-borne instruments to measure ozone directly over the South Pole. By October 9, the total column ozone had plunged to 93 DU from approximately 300 DU in mid-July. More importantly, nearly all of the ozone in the layer between 8 and 13 miles above the Earth's surface had been destroyed. In this critical layer, the instrument measured a record low of only 1.2 DU, having rapidly plunged from an average non-hole reading of 125 DU in July and August.

"These numbers mean the ozone is virtually gone in this layer of the atmosphere," said **David Hofmann**, Director of the Global Monitoring Division at the NOAA Earth System Research Laboratory. "The depleted layer has an unusual vertical extent this year, so it appears that the 2006 ozone hole will go down as a record-setter."

Observations by Aura's Microwave Limb Sounder show extremely high levels of ozone destroying chlorine chemicals in the lower stratosphere (approximately

From September 21-30, 2006 the average area of the ozone hole was the largest ever observed, at 10.6 million square miles. In this image, from September 24, the Antarctic ozone hole was equal to the record single-day largest area of 11.4 million square miles, reached on September 9, 2000. Satellite instruments monitor the ozone layer, and we use their data to create the images that depict the amount of ozone. The darkest areas are where there is the least ozone. **Credit:** NASA



12.4 mi high). These high chlorine values covered the entire Antarctic region in mid to late September. The high chlorine levels were accompanied by extremely low values of ozone.

The temperature of the Antarctic stratosphere causes the severity of the ozone hole to vary from year to year. Colder than average temperatures result in larger and deeper ozone holes, while warmer temperatures lead to smaller ones. The NOAA National Centers for Environmental Prediction (NCEP) provided analyses of satellite and balloon stratospheric temperature observations. The temperature readings from NOAA satellites and balloons during late September 2006, showed the lower stratosphere at the rim of Antarctica was approximately nine degrees Fahrenheit colder than average, increasing the size of this year's ozone hole by 1.2 to 1.5 million mi<sup>2</sup>.

The Antarctic stratosphere warms by the return of sunlight at the end of the polar winter and by large-scale weather systems (planetary-scale waves) that form in the troposphere and move upward into the stratosphere. During the 2006 Antarctic winter and spring, these planetary-scale wave systems were relatively weak, causing the stratosphere to be colder than average. As a result of the Montreal Protocol and its amendments, the concentrations of ozone-depleting substances in the lower atmosphere (troposphere) peaked around 1995 and are decreasing in both the tropo-

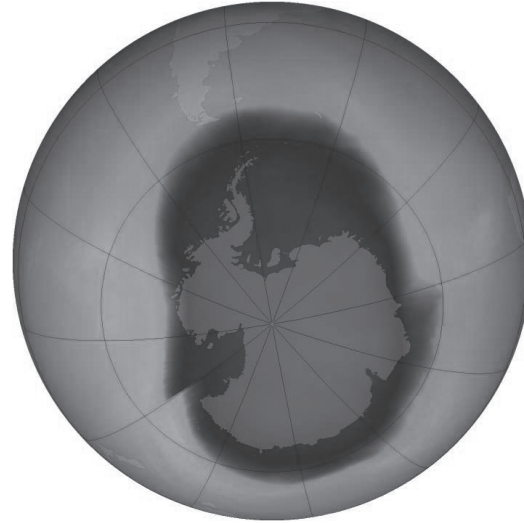


sphere and stratosphere. It is estimated these gases reached peak levels in the Antarctica stratosphere in 2001. However, these ozone-depleting substances typically have very long lifetimes in the atmosphere—more than 40 years.

As a result of this slow decline, the ozone hole is estimated to very slowly decrease in area by about 0.1 to 0.2% annually for the next 5 to 10 years. This slow decrease is masked by large year-to-year variations caused by Antarctic stratosphere weather fluctuations.

The recently completed 2006 World Meteorological Organization/United Nations Environment Programme Scientific Assessment of Ozone Depletion concluded the ozone hole recovery would be masked by annual variability for the near future and the ozone hole would fully recover in approximately 2065.

“We now have the largest ozone hole on record for this time of year,” said **Craig Long** of NCEP. As the sun rises higher in the sky during October and November, this unusually large and persistent area may allow much more ultraviolet light than usual to reach Earth’s surface in the southern latitudes. ■



The ozone hole of 2006 is the most severe ozone hole (least amount of ozone) observed to date. NASA’s Aura satellite observed a low value of 85 Dobson Units (DU) on October 8 in a region over the East Antarctic ice sheet. Dobson Units are a measure of ozone amounts above a fixed point in the atmosphere. This severe ozone hole resulted from the very high ozone depleting substance levels and the record cold conditions in the Antarctic stratosphere. **Credit:** NASA

## Public Release of Aura-OMI NO<sub>2</sub> Product

*Steve Kempler, Goddard Space Flight Center, Steven.J.Kempler@nasa.gov*

NASA’s Aura satellite sensors since its launch in July 2004, have been tracking important atmospheric pollutants from space. The Ozone Monitoring Instrument (OMI), one of the four Aura satellite sensors, provides daily global measurements of four of the important U.S. Environmental Protection Agency’s criteria pollutants (tropospheric ozone (O<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>), sulfur dioxide (SO<sub>2</sub>), and aerosols from biomass burning and industrial emissions), and it provides surface UV irradiance, all of which are a threat to human health.

The Nitrogen Dioxide Product *OMNO2* from the Aura OMI is now publicly available from NASA’s Goddard Space Flight Center (GSFC) Earth Sciences (GES) Data and Information Services Center (DISC) for public access. *OMNO2* contains slant column NO<sub>2</sub>—total amount along the optical path from the sun into the atmosphere, and then toward the satellite—the total vertical column NO<sub>2</sub>, the estimated tropospheric contribution to the total NO<sub>2</sub> column, NO<sub>2</sub> column hidden by any clouds in the OMI field of view, and other ancillary data.

Nitrogen dioxide is an important chemical species in both the stratosphere, where it plays a key role in ozone chemistry, and in the troposphere, where it is a precursor to ozone production. In the troposphere, it is produced in various combustion processes and lightning, and is an indicator of poor air quality.

OMI data are processed at the OMI Science Investigator-led Processing System (OSIPS) at NASA/GSFC, the OMI Dutch Processing System (ODAPS) at KNMI, the Netherlands, and at FMI, Finland. After quick validation of the OMI products with *in-situ* measurements by the validation team, the standard OMI derived products are made broadly available from the GES DISC Atmospheric Composition webpage—[acd.disc.gsfc.nasa.gov/](http://acd.disc.gsfc.nasa.gov/).

The full set of Aura products from the Aura sensors OMI, MLS, and HIRDLS, are available from the GES DISC at [disc.sci.gsfc.nasa.gov/Aura/data\\_products.shtml](http://disc.sci.gsfc.nasa.gov/Aura/data_products.shtml). Aura products from the TES sensor are available from the NASA Langley Atmospheric Data Center.

## Greenland Ice Sheet on a Downward Slide

Stephen Cole, NASA Goddard Space Flight Center, [scole@pop600.gsfc.nasa.gov](mailto:scole@pop600.gsfc.nasa.gov)

For the first time NASA scientists have analyzed data from direct, detailed satellite measurements to show that ice losses now far surpass ice gains in the shrinking Greenland ice sheet.

Using a novel technique that reveals regional changes in the weight of the massive ice sheet across the entire continent, scientists at NASA's Goddard Space Flight Center, Greenbelt, MD, report that Greenland's low coastal regions lost 155 Gt (41 mi<sup>2</sup>) of ice per year between 2003 and 2005 from excess melting and icebergs, while the high-elevation interior gained 54 Gt (14 mi<sup>2</sup>) annually from excess snowfall.

"With this new analysis we observe dramatic ice mass losses concentrated in the low-elevation coastal regions, with nearly half of the loss coming from south-east Greenland," said lead author **Scott Luthcke** of NASA Goddard's Planetary Geodynamics Laboratory. "In the 1990's the ice was very close to balance with gains at about the same level as losses. That situation has now changed significantly, with an annual net loss of ice equal to nearly six years of average water flow from the Colorado River."

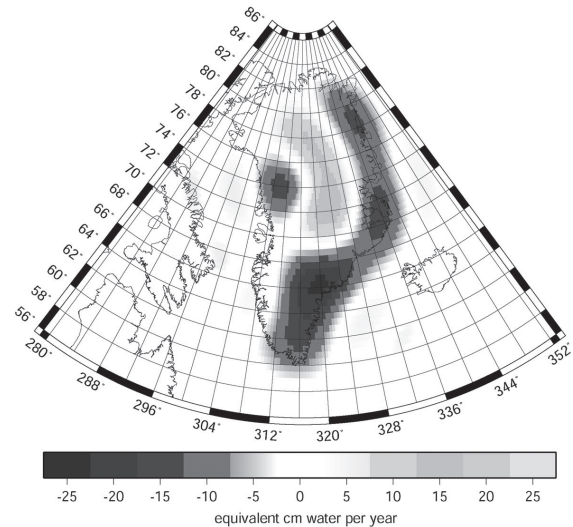
The study is based on an innovative use of data from the Gravity Recovery and Climate Experiment (GRACE) satellite that reveals detailed information about where and when the Greenland ice mass has changed. Other recent studies using GRACE observations have reported continent-wide ice mass declines, but none has shown these changes in enough detail for



Greenland's massive ice sheet has lost nearly 100 Gt of ice annually recently, much of it in low-elevation regions along the continent's southeastern coast, including the southern tip (pictured here). **Credit:** NASA MODIS Land Rapid Response Team

NASA satellite data has revealed regional changes in the weight of the Greenland ice sheet between 2003 and 2005. Low coastal regions (darkest areas) lost three times as much ice per year from excess melting and icebergs than the high-elevation interior (lighter areas) gained from excess snowfall. **Credit:** Scott Luthcke, NASA Goddard

### Greenland Mass Trend from GRACE



scientists to investigate how much different areas of the ice sheet are losing.

To achieve this more-detailed view of the ice sheet's behavior, Luthcke and his colleagues used a technique that brings GRACE's global view of the Earth down to a more local and frequent view. The pair of GRACE satellites orbiting in close formation detect changes in the Earth's mass directly below them by measuring changes in the distance between the two satellites as the gravitational force of the mass causes each to speed up or slow down.

Standard GRACE data products infer local mass changes from a global data set of these satellite measurements. The new study used only data from over the Greenland region.

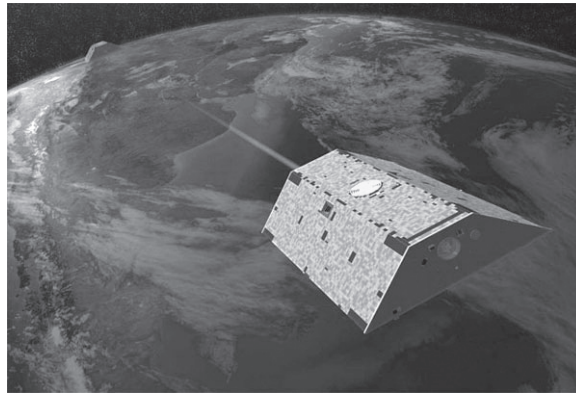
"With this new detailed view of the Greenland ice sheet, we have come a long way toward resolving the differences among recent observations and what we know about how the ice sheet behaves," said co-author **Waleed Abdalati**, head of Goddard's Cryospheric Sciences Branch. "A consistent picture from the different datasets is emerging."

"The seasonal cycle of increased mass loss during the summer melt season and growth during winter is clearly captured," said co-author **Jay Zwally**, ICESat project scientist. The new results also capture more

precisely where changes are taking place, showing that the losses of ice mass are occurring in the same three drainage systems where other studies have reported increased glacier flow and ice-quakes in outlet glaciers.

GRACE is a joint partnership between NASA and the German Aerospace Center, Deutsches Zentrum für Luft und Raumfahrt. The satellites, launched in 2002, are managed by the Jet Propulsion Laboratory.

The authors point out that continued monitoring is needed to determine whether or not this ice loss represents a long-term trend. The new study appeared in *Science Express*, the advance edition of the journal *Science*, on October 19. ■



The changes in the ice sheet's mass were measured from space by the GRACE mission. GRACE is a pair of satellites orbiting in close formation that can detect changes in the Earth's mass directly below them by measuring changes in the distance between the two spacecraft as the gravitational force of the mass causes each to speed up or slow down. **Credit:** NASA

## New CERES Data Products from ASDC Available

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center in collaboration with the CERES Science Team announces the release of the following datasets for the time period July 2002 - December 2005:

- CER\_SFC\_Aqua-FM3-MODIS\_Edition2A
- CER\_SFC\_Aqua-FM4-MODIS\_Edition2A

The Monthly Gridded TOA/Surface Fluxes and Clouds (SFC) data product contains hourly single satellite surface/top-of-atmosphere flux and cloud parameters averaged over 1.0° regions. For each instrument, there are 36 SFC files per month and each file contains five 1.0° latitude zones. The Aqua Edition2A SFC data set supersedes Edition1B which was publicly released in April 2005.

Information about the CERES products, including products available, documentation, relevant links, sample software, tools for working with the data, etc. can be found at the CERES data table: [eosweb.larc.nasa.gov/PRODOCS/ceres/table\\_ceres.html](http://eosweb.larc.nasa.gov/PRODOCS/ceres/table_ceres.html)

### HOW TO CONTACT US

For information regarding our data holdings or for assistance in placing an order, please contact:

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 NASA Langley Research Center  
 Users and Data Services  
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 Hampton, VA 23681-2199  
 Phone: 757-864-8656  
 E-mail: [larc@eos.nasa.gov](mailto:larc@eos.nasa.gov)  
 URL: [eosweb.larc.nasa.gov](http://eosweb.larc.nasa.gov)

## Central American Fires Impact U.S. Air Quality and Climate

Mike Bettwy, NASA Goddard Space Flight Center, mbettwy@aol.com

Scientists using NASA satellites and computer models have shown that pollutants from Central American biomass burning can influence air quality and climate in the United States.

A NASA-funded study published in the July 26, 2006, *Journal of Geophysical Research-Atmospheres* found that during April-May 2003, large amounts of smoke, which include aerosols—tiny particles suspended in the air—from biomass burning in the Yucatan Peninsula and southern Mexico reached Texas, Oklahoma, and other areas in the southeastern United States.

The smoke plumes degraded visibility and air quality in coastal regions along the Gulf of Mexico and resulted in the greatest concentration of small particulate matter in southern Texas since 1998. By blocking incoming sunlight, the smoke plumes also cooled surface air temperatures over land. But higher in the atmosphere the smoke absorbed solar radiation and warmed temperatures. This created a circulation pattern that trapped smoke aerosols in the lower atmosphere, worsening air quality.

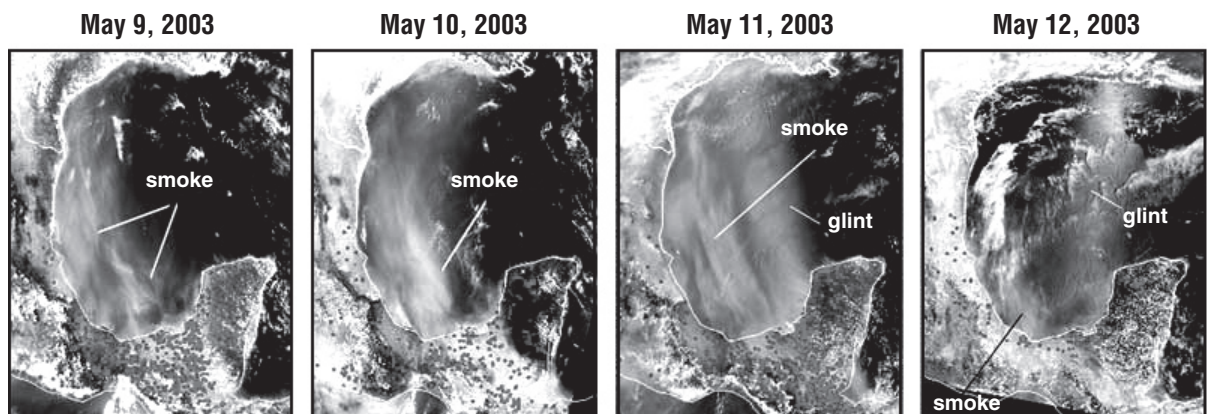
The researchers used a newly developed computer model to simulate the transport and effects of smoke in the atmosphere and on the Earth's surface. The model couples aerosol properties with meteorology and uses hourly smoke emission data from the NASA-led Fire Locating and Monitoring of Burning Emissions (FLAMBE) project. FLAMBE is a joint effort by NASA, the U.S. Navy, the National Oceanic and Atmospheric Administration and university partners to develop smoke aerosol forecasting models for the benefit of the global weather community.

“Although this computer model is not currently used in air-quality and weather forecasting, it is superior to other models for this purpose because it explicitly accounts for the diurnal variation of smoke emission from biomass burning fires and the radiative impacts of aerosols so that their impact on meteorology can be studied,” said study co-author **Sundar Christopher** of the University of Alabama, Huntsville, AL.

Comparisons with ground-based observations and imagery from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua Earth Observing System satellites showed that the model accurately simulated the impact of smoke on air temperature and the amount of sunlight absorbed and scattered through the atmosphere.

MODIS data was particularly useful in determining how aerosols from the Central American fires affected the amount of sunlight passing through the atmosphere, which can impact surface and atmospheric temperatures. “MODIS data allows us to capture the meteorological impacts of smoke and aerosols, especially important during the tropical dry season each spring when biomass burning peaks and pollutants are transported to the United States,” said Christopher.

Smoke particles and aerosols scatter incoming sunlight while black carbon aerosols absorb solar radiation, affecting the atmospheric temperature profile. In turn, this alters evaporation and cloud formation. Smoke particles also often act as cloud condensation nuclei—small particles on which water vapor condenses and forms clouds—influencing the formation and distribution of rainfall. When combined with certain



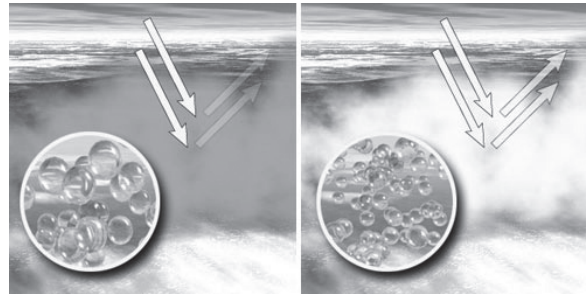
These images from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua satellites on May 9-12, 2003, shows the transport of smoke plumes. The small dots on the lower portion of the images indicate the location of fires. **Credit:** Jun Wang and Sundar Christopher/University of Alabama-Huntsville

weather patterns, these aerosols can also have a significant impact on local and regional air quality according to the study.

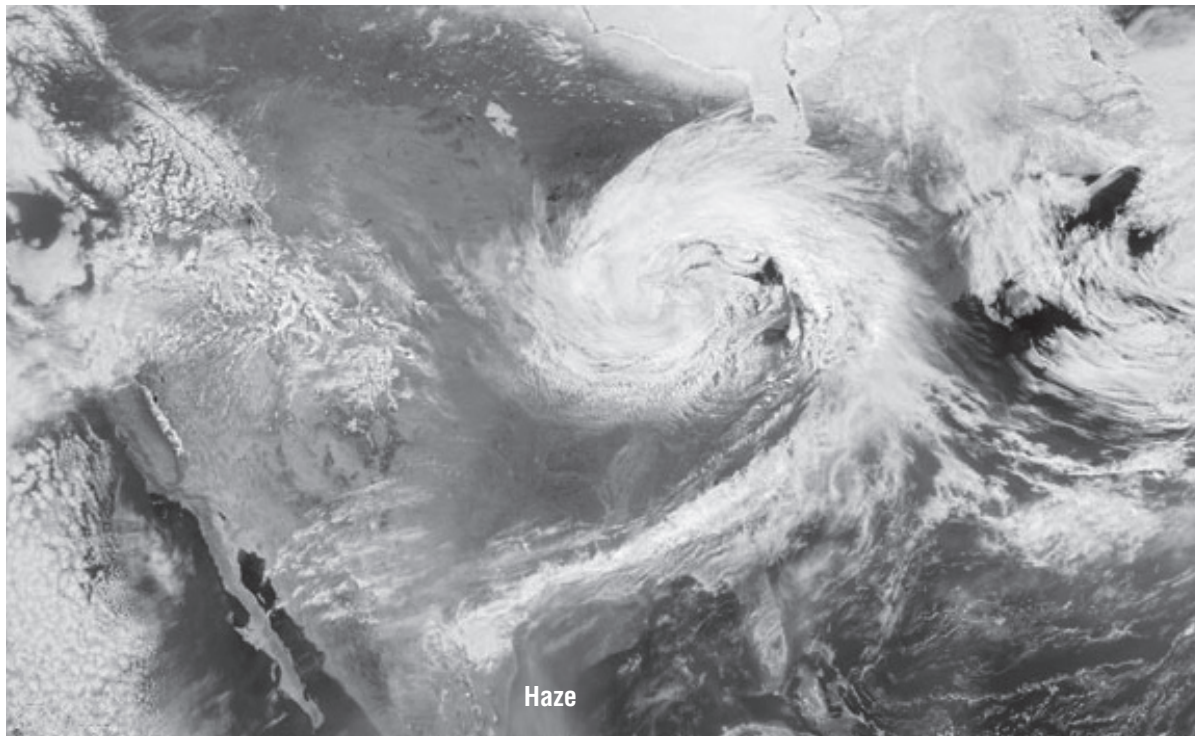
This work demonstrated a new capability to improve air quality and climate forecasts, but researchers need to learn more about how smoke and aerosols impact clouds. “New satellite data, including that from the joint NASA and French Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite, should help us better understand cloud microphysical processes and how aerosols impact cloud formation,” said Christopher. Combining this information with improved computer models will help scientists better understand the role of smoke and aerosols on the climate to improve forecasts, even when the pollutant source is thousands of miles away.

In addition to Christopher, other authors of this and a previous related study included former NASA Earth System Science fellow **Jun Wang** of Harvard University; **Udaysankar Nair**, University of Alabama-Hunts-

ville; **Jeffrey Reid**, Naval Research Laboratory; **Jenny Hand**, Colorado State University; **Jim Szykman**, NASA Langley Research Center; and **Elaine Prins**, University of Wisconsin. ■



The left image shows clouds with low aerosol concentrations and a few large droplets that do not scatter light well, and allow much of the Sun's light to pass through and reach the surface. The right image shows clouds with high aerosol concentrations that provide the nucleation points necessary for the formation of many small liquid water droplets. Up to 90% of visible light is reflected back to space by such clouds without reaching Earth's surface. **Credit:** NASA



This May 11, 2003, Sea-viewing Wide Field-of-view Sensor (SeaWiFS) image shows that much of the country's weather was dominated by a low-pressure system centered near Lake Michigan. The system carried smoke from the fires across Central America into the Gulf Coast states and northern Caribbean. The haze just left of the bottom center of this image is smoke from the fires burning in Central America. **Credit:** NASA

## The Lightning Imaging Sensor (LIS) Science Team Announces the Release of Version 2.2 of the LIS/OTD 11 Year Climatology Dataset

This release includes updates to the six existing datasets and the addition of four new datasets. The datasets have been updated through December 2005, except for the time series datasets which have been updated through April 2006. These datasets can be ordered from the Global Hydrology Resource Center (GHRC) using HyDRO—[ghrc.nsstc.nasa.gov/hydro-cgi/bin/execute?hydro+search](http://ghrc.nsstc.nasa.gov/hydro-cgi/bin/execute?hydro+search)—or downloaded from the Thunder website at [thunder.nsstc.nasa.gov/data/#GRIDDED\\_DATA](http://thunder.nsstc.nasa.gov/data/#GRIDDED_DATA). Below are the dataset names and a short description of each dataset.

*All datasets listed below include climatologies from the 5-year OTD (4/95-3/00) and 8-year LIS (1/98-12/05) missions are included, as well as a combined OTD+LIS climatology and supporting base data (flash counts and viewing times). Best-available detection efficiency corrections and instrument cross-normalizations have been applied.*

### **LIS/OTD 0.5° High Resolution Full Climatology (HRFC)**

The LIS/OTD 0.5° High Resolution Full Climatology product is a 0.5° x 0.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 2.5° Low Resolution Annual Climatology (LRAC)**

The LIS/OTD 2.5° Low Resolution Annual Climatology product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 2.5° Low Resolution Diurnal Climatology (LRDC)**

The LIS/OTD 2.5° Low Resolution Diurnal Climatology product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 2.5° Low Resolution Full Climatology (LRFC)**

The LIS/OTD 2.5° Low Resolution Full Climatology product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 0.5° High Resolution Monthly Climatology (HRMC)**

The LIS/OTD 0.5° High Resolution Monthly Climatology product is a 0.5° x 0.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 0.5° High Resolution Annual Climatology (HRAC)**

The product is a 0.5° x 0.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 2.5° Low Resolution Annual Diurnal Climatology (LRADC)**

The LIS/OTD 0.5° High Resolution Annual Climatology product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

*The following datasets are the same as above, except the 8-year LIS data covers 1/98-4/06.*

### **LIS/OTD 2.5° Low Resolution Time Series (LRTS)**

The LIS/OTD 2.5° Low Resolution Time Series product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 2.5° Low Resolution Monthly Time Series (LRMTS)**

The LIS/OTD 2.5° Low Resolution Monthly Time Series product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

### **LIS/OTD 2.5° Low Resolution Annual Climatology Time Series (LRACTS)**

The LIS/OTD 2.5° Low Resolution Annual Climatology Time Series product is a 2.5° x 2.5° gridded composite of total (IC+CG) lightning bulk production, expressed as a flash rate density (fl/km<sup>2</sup>/yr).

You can find more information about these datasets as well as others at [ghrc.nsstc.nasa.gov/](http://ghrc.nsstc.nasa.gov/).

Please let us know if you have any questions or comments.

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## Get Involved with NASA Science at the Fall AGU!

*December 11-15, 2006, San Francisco, CA*

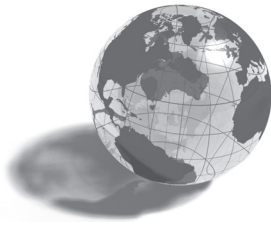
Join us at NASA's booth **Tuesday, December 12 through Thursday, December 14**, for an opportunity to hear live presentations from, and network with, scientists from across the agency.

The presentations will cover the width and breadth of the agency's activities and include a wide range of topics including how to access NASA data, scientific visualization techniques, and highlights of the latest science results. An agenda\* listing the presentations planned each day is now posted on the Earth Observing System Project Science Office (EOSPSO) Web Page—[eosps0.gsfc.nasa.gov](http://eosps0.gsfc.nasa.gov), click on *Scheduled Presentations*. The agenda includes titles of presentations, speakers' names, and a short description of each presentation. Approximate start times are also listed.

In addition to the science presentations, on Friday, December 15, **students get involved!** The AGU's Student EXPloration of Research in the Earth and Space Sciences (EXPRESS) program brings together approximately 600 students from local middle schools for a tour of the AGU exhibit hall to learn more about research and careers in Earth and Space science. NASA will partner with the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), and Incorporated Research Institutions for Seismology (IRIS) to facilitate educational activities for students, including a scavenger hunt and interactive presentations on both Earth and Space science.

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\*Please note that the agenda is not yet final and may be subject to change between now and the AGU. Be sure to check the EOSPSO website for the latest information before coming to the meeting.



## EOS Scientists in the News

Stephen Cole, [scole@pop600.gsfc.nasa.gov](mailto:scole@pop600.gsfc.nasa.gov), NASA Earth Science News Team  
Mike Bettwy, [mbettwy@aol.com](mailto:mbettwy@aol.com), NASA Earth Science News Team

**Central American Fires Impact U.S. Air Quality, Climate**, October 10; *United Press International*, *LiveScience.com*, *Pollution Online*. Using NASA satellites and computer models, **Sundar Christopher** (University of Alabama in Huntsville) finds that pollutants from Central American biomass burning can influence air quality and climate in the southern United States.

**NASA Data Captures El Niño's Return in the Pacific**, October 5; *United Press International*. NASA satellite data indicates El Niño has returned to the tropical Pacific Ocean, although in a relatively weak condition that may not persist, reports **Bill Patzert** (NASA JPL).

**NASA Satellite Data Helps Assess the Health of Florida's Coral Reef**, October 3; *United Press International*, *PhysOrg.com*. NASA satellite data was used to help monitor the health of Florida's coral reef as part of a field research effort this summer involving a team of scientists led by **Christopher Moses** (University of South Florida).

**NASA Preparing for Delayed UAV Forest Fire Flights**, October 3; *Aerospace Daily and Defense Report*. **Frank Cutler** (NASA Dryden) discusses delays in the Western States Unmanned Aerial Vehicles Fire Mission and use of UAVs to conduct science research.

**Global Lightning Study Promises Fresh Insight into Severe-Storm Behavior**, October 2; *First Coast News (Florida)*. Data from two unique NASA satellite instruments is giving researchers a comprehensive picture of worldwide lightning activity that may yield new insight into the relationship between global climate and weather patterns, report **Steve Goodman** (NASA MSFC), **Rich Blakeslee** (NASA MSFC), **Hugh Christian** (University of Alabama in Huntsville), and **Douglas March** (University of Alabama in Huntsville).

**NASA Sees Ozone Hole Approach Annual Peak**, September 28; *Guardian Unlimited (UK)*, *Hamilton Spectator (Canada)*, *LiveScience.com*. NASA scientists led by **Paul Newman** (NASA GSFC) are using the latest tools to monitor the annual peak in the Antarctic ozone hole and are sharing information with the public on the Ozone Watch web site.

**Stormy Flying Captures Hurricane Birth**, September 26; *Scientific American (online)*. **Robbie Hood** (NASA MSFC) discusses research flights and other storm-monitoring activities that took place as part of the NASA Afri-

can Monsoon Multidisciplinary Analyses field campaign off the African coast this summer.

**NASA Technology Captures Massive Hurricane Waves**, September 26; *United Press International*, *Fox News*, *LiveScience.com*. NASA researchers **Edward Walsh** (NASA Wallops) and **Wayne Wright** (NASA Wallops) are using NASA technology to increase knowledge about the behavior of hurricane waves that pose a serious threat to mariners and coastal communities.

**NASA Study Finds World Warmth Edging Ancient Levels**, September 25; *Associated Press*, *Reuters*, *BBC*, *CNN*. A new study by climatologists including **James Hansen** (NASA GISS), **David Lea** (University of California-Santa Barbara), and **Martin Medina-Elizade** (University of California-Santa Barbara) finds that the world's temperature is reaching a level that has not been seen in thousands of years.

**NASA Study Tracks Global Sources, Transport of Air Pollution**, September 25; *EIN News*, *Economist.com*. For the first time, scientists used simultaneous observations of carbon monoxide and ozone from space to distinguish between ozone produced by human activity and that produced by natural sources, report researchers **Daniel Jacob** (NASA JPL), **Lin Zhang** (NASA JPL), and **Helen Worden** (NASA JPL).

**Short-Term Ocean Cooling Suggests Global Warming 'Speed Bump'**, September 21; *United Press International*, *MSNBC*, *Earth & Sky Radio program*. Scientists including **Josh Willis** (NASA JPL) and **John Lyman** (NOAA) find the average temperature of the upper oceans has significantly cooled since 2003, but that the decline is a fraction of the total ocean warming over the previous 48 years.

**'Imported' Pollution Tied to Poor Air Quality in Texas**, September 21; *United Press International*, *The Washington Times*. A NASA-funded study led by **Gary Morris** (Valparaiso University) concludes that ozone pollution levels increased significantly in the air above Houston in July 2004, in part due to smoke transported into the area from forest fires raging in Alaska and Canada.

**NASA's TRMM Satellite Tracks 2006 Hurricane Rainfall**, September 20; *Space Daily*, *Terra Daily*, *Innovations Report*. Scientists **Bob Adler** (NASA GSFC), **George Huffman** (NASA GSFC), and **Scott Braun** (NASA GSFC) are using satellite data from the Tropical Rainfall



Measuring Mission to determine the amount of rainfall that falls in the path of a hurricane.

**Growth in Amazon Cropland May Impact Climate and Deforestation Patterns**, September 19; *United Press International, Environment News Service*. **Douglas Morton** (University of Maryland), **Ruth DeFries** (University of Maryland), and **Lahouari Bounoua** (NASA GSFC) used NASA satellite data to find that forest clearing for mechanized cropland in the Brazilian Amazon may alter the region's climate and the land's ability to absorb carbon dioxide.

**NASA's Earth Observing System Receives 2006 Space Systems Award**, September 19; *Space Today, Yahoo News*. Earth Observing System Senior Project Scientist **Michael King** (NASA GSFC) accepted an award on behalf of NASA for their efforts to measure global climate change.

**Arctic Ice Meltdown Continues With Significantly Reduced Winter Ice Cover**, September 13; *Associated Press, Reuters, United Press International, Scripps-Howard News Service*. A new study led by **Joey Comiso** (NASA GSFC) shows that in the last two years sea ice has been shrinking on the surface of Arctic waters to record low levels.

**Warming Climate May Put Chill on Arctic Polar Bear Population**, September 13; *United Press International, The Boston Globe, Discovery.com, LiveScience.com*. According to research by scientists **Claire Parkinson** (NASA GSFC) and **Ian Stirling** (Canadian Wildlife Service), the recent rise in Arctic polar bear sightings is probably related to retreating sea ice triggered by climate warming, and not population increases.

**NASA Sees Rapid Changes in Arctic Sea Ice**, September 13; *Associated Press, CNN, NBC, The New York Times*. NASA data shows that Arctic perennial sea ice, which normally survives the summer melt season and remains year-round, shrunk abruptly by 14% between 2004 and 2005, finds a research team led by **Son Nghiem** (NASA JPL).

**El Niño Has Formed**, September 13; *KPCC Public Radio (Los Angeles), KABC-TV (Los Angeles), San Diego Union Tribune*. In response to the National Oceanic and Atmospheric Administration's announcement that El Niño has formed and will last into 2007, **Bill Patzert** (NASA JPL) provides additional details on its current strength and how it may impact California's winter weather.

**Scientists Converge to Unlock Hurricane Mystery**, September 13; *Times of Oman, Khaleej Times (United Arab Emirates)*. **Robbie Hood** (NASA MSFC) discusses a month-long hurricane research expedition off the coast of Africa that could contribute to better hurricane forecasts.

**Wildfires Char Western States**, September 9; *NBC Nightly News*. **Bill Patzert** (NASA JPL) is interviewed for

a story about the record-setting wildfire season and the short-term outlook.

**Asian Summer Monsoon Stirred by Dust in the Wind**, September 7; *Science Daily, Terra Daily*. According to a new NASA study by **William Lau** (NASA GSFC), dust from deserts collects in the atmosphere against the slopes of South Asia's Tibetan Plateau during the region's monsoon season and helps trigger rainfall.

**What Is It Like to Be on a NASA Hurricane Mission?**, September 5; *Fresno.com, Space Daily, Terra Daily*. A team of scientists including **Edward Zipser** (University of Utah) and **Jeff Halverson** (University of Maryland-Baltimore County) used airplanes, computer modeling programs, and NASA satellites to study hurricanes off the African coast this summer.

**NASA, NOAA Data Indicate Ozone Layer is Recovering**, August 31; *Reuters, United Press International, ABC*. A study using NASA and National Oceanic and Atmospheric Administration (NOAA) data finds consistent evidence that Earth's ozone layer is on the mend, say researchers **Eun-Su Yang** (Georgia Institute of Technology), **Mike Newchurch** (University of Alabama in Huntsville), and **Ross Salawitch** (NASA JPL).

**NASA Study Solves Ocean Plant Mystery**, August 31; *United Press International, BBC, Scientific American, Voice of America*. New research by **Michael Behrenfeld** (Oregon State University), **Scott Doney** (Woods Hole Oceanographic Institution), and **Oscar Schofield** (Rutgers University) suggests that nitrogen is the primary element missing for algae growth and photosynthesis in the tropical Pacific, a finding that will help researchers better understand how marine ecosystems respond to climate change.

**Rip Currents: A Danger at the Beach**, August 30; *Los Angeles Times*. **Bill Patzert** (NASA JPL) contributed to a story describing the science of rip currents that typically move at 1-2 feet per second but can rapidly increase in speed near shorelines.

**NASA Satellites Can See How Climate Change Affects Forests**, August 29; *The Register (UK), Yahoo News, PhysOrg.com*. A NASA-funded study led by **Richard Waring** (Oregon State University) shows that NASA satellite data can provide new details on forest growth and health, helping track the impacts of our changing planet.

*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.*

## NASA Science Mission Directorate – Science Education Update

Ming-Ying Wei, [mwei@hq.nasa.gov](mailto:mwei@hq.nasa.gov), NASA Headquarters

Liz Burck, [Liz.B.Burck@nasa.gov](mailto:Liz.B.Burck@nasa.gov), NASA Headquarters

Theresa Schwerin, [theresa\\_schwerin@strategies.org](mailto:theresa_schwerin@strategies.org), IGES

### CELEBRATE THE INTERNATIONAL POLAR YEAR WITH NASA, NOAA, AND NSF AT REGIONAL NSTA, SALT LAKE CITY, December 8, 2006

In celebration of the International Polar Year (IPY), the Fragile Ice Symposium designed for grades 5-8 educators will delve into IPY-related science content and educational activities developed by NASA, NOAA, and NSF. This event is a blended professional development experience that includes this face-to-face learning opportunity at the conference followed by several online experiences designed to extend the interactivity between the participants and the presenters. Participants will pay a \$44 advance registration fee or \$49 onsite at the conference. For more information and to register, visit [institute.nsta.org/fall06/ipyice/symposium.asp](http://institute.nsta.org/fall06/ipyice/symposium.asp).

### NASA SOFTWARE ACHIEVES BREAKTHROUGH IN ACCESSIBILITY BY BLIND USERS

NASA recently released an innovative *Open Source* software suite that may forever change how blind and vision-impaired users *see* complex graphs. The Math Description Engine Software Development Kit (MDE SDK) is a reusable software library that generates text, sound and visual representations of graphs found in both math and science applications. Visually-impaired computer users access these alternative text and sound descriptions through the use of a screen reader and standard computer speakers.

The MDE distinguishes itself from other accessibility software by determining the key characteristics of a graph “on the fly.” Using this determination, it builds natural-language text descriptions that enable visually-impaired users to view spatial relationships through sound alone.

MDE technology serves as a powerful learning tool for sighted users as well. Acting as a virtual math and science assistant, NASA’s *MathTrax* engages both the eyes and ears of students to increase overall comprehension.

The MDE software library was created by NASA’s Information Accessibility Lab (IAL), under the direction of Robert O. Shelton, a blind mathematician. The MDE SDK is currently available for download under an Open Source license at [prime.jsc.nasa.gov/mde](http://prime.jsc.nasa.gov/mde). Visit the site to learn more about the program and to play

an integral role in developing the future of accessible graphing technology. To learn more about the MDE SDK or *MathTrax*, please email the team at [info@prime.jsc.nasa.gov](mailto:info@prime.jsc.nasa.gov)

### COALITION FOR EARTH SCIENCE EDUCATION (CESE) NOVEMBER MEETING RESCHEDULED FOR MARCH 2-3, 2007

The November 2006 Coalition for Earth Science Education (CESE) meeting in Boulder, Colorado has been rescheduled for March 2-3, 2007, at the University Corporation for Atmospheric Research (UCAR) Center Green campus. All educators and scientists working on Earth system science education in formal and informal settings are encouraged to attend. For more information, visit [esdepo.gsfc.nasa.gov/calendar/view.php?id=109&year=2007&month=03&day=02](http://esdepo.gsfc.nasa.gov/calendar/view.php?id=109&year=2007&month=03&day=02).

### EXPLORATORIUM WEBCAST SERIES FROM THE SOUTH POLE

During November-December 2006, the Exploratorium, a hands-on museum in San Francisco, will have a series of webcasts from the South Pole. They are also planning webcasts originating from the Exploratorium on global warming and the poles. For more information, visit the Exploratorium’s calendar of upcoming events at: [sodium.exploratorium.edu/cgi-bin/call/webevent.cgi?cmd=opencal&cal=cal6&](http://sodium.exploratorium.edu/cgi-bin/call/webevent.cgi?cmd=opencal&cal=cal6&).

### PLAY & LEARN WITH NASA

Play and Learn is a new category of online resources available in the education section of [NASA.gov](http://NASA.gov). This section contains fun and engaging education supplements. The items can be printed for instructional use, game time or just to make learning more fun. Visit [www.nasa.gov/audience/foreducators/topnav/materials/listbytype/By\\_Type\\_Play\\_and\\_Learn\\_landingpage.html](http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/By_Type_Play_and_Learn_landingpage.html)

### SCIENCE AND APPLICATIONS NEWS

For the latest NASA Earth science news, visit the NASA Earth Observatory—[earthobservatory.nasa.gov](http://earthobservatory.nasa.gov)—or Science@NASA—[science@nasa.gov](mailto:science@nasa.gov). Science@NASA stories are also available as podcasts, as well as translated into Spanish at their sister site, Ciencia@NASA—[ciencia.nasa.gov/](http://ciencia.nasa.gov/). ■

## EOS Science Calendar

### December 7-8

MISR Data Users Science Symposium, California Institute of Technology, Pasadena, CA. URL: [www-misr2.jpl.nasa.gov/events/events.html](http://www-misr2.jpl.nasa.gov/events/events.html).

2007

### March 6-9

AIRS Science Team Meeting, Pasadena, CA. URL: [airs.jpl.nasa.gov](http://airs.jpl.nasa.gov)

### October 1-5

Aura Science Team Meeting, Pasadena, CA. URL: [aura.gsfc.nasa.gov](http://aura.gsfc.nasa.gov)

## Global Change Calendar

### December 4-14

International Joint Conferences on Computer, Information, and Systems Sciences, University of Bridgeport, CT. URL: [www.cisse2006online.org/](http://www.cisse2006online.org/)

### December 11-15

American Geophysical Union (AGU) Fall Meeting, San Francisco, CA. URL: [www.agu.org/meetings/fm06/](http://www.agu.org/meetings/fm06/)

2007

### January 14-18

2007 American Meteorological Society (AMS) Annual Meeting, San Antonio, TX. URL: [www.ametsoc.org/meet/annual/index.html](http://www.ametsoc.org/meet/annual/index.html)

### February 12-15

International Symposium on Signal Processing and its Applications (ISSPA), Sharjah, United Arab Emirates. URL: [www.isspa07.org/](http://www.isspa07.org/)

### March 3-10

IEEE/AIAA Aerospace Conference: Global Earth Observation System of Systems (GEOSS), Big Sky, Montana. Call for Papers. Contact: Kathy Fontaine, [Kathy.Fontaine@nasa.gov](mailto:Kathy.Fontaine@nasa.gov). URL: [www.aeroconf.org](http://www.aeroconf.org)

### April 17-20

IEEE Radar Conference 2007, Boston, MA. URL: [www.radar2007.org/](http://www.radar2007.org/)

### May 23-25

Joint CIG/ISPRS Conference on Geomatics for Disaster and Risk Management, Toronto, Ontario Canada. URL: [www.cig-acsg.ca/cig2007/english/home.htm](http://www.cig-acsg.ca/cig2007/english/home.htm)

### June 4-8

2007 International Waveform Diversity & Design Conference, Pisa, Italy. URL: [www.waveformdiversity.org](http://www.waveformdiversity.org)

### June 25-29

32nd International Symposium on the Remote Sensing of the Environment (ISRSE), San Jose, Costa Rica. URL: [www.cenat.ac.cr/simposio/welcome.htm](http://www.cenat.ac.cr/simposio/welcome.htm)

Along the coast of Dubai—one of several emirates comprising the United Arab Emirates—are human-made islands. When the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite took this picture on September 18, 2006, these islands were the largest artificial islands in the world. All of the islands were still under some degree of construction in the fall of 2006.

From south to north, the artificial island sites in this image are Palm Jebel Ali, Palm Jumeirah, The World, and Palm Deira. Palm Jebel Ali and Palm Jumeirah appear largely complete in this image, looking like giant palm trees enclosed in huge arcs. In between Palm Jumeirah and the site for Palm Deira is the site for The World, which, when complete, will resemble a world map. **Image credit:** NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.





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National Aeronautics and Space Administration

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### **The Earth Observer**

*The Earth Observer* is published by the EOS Project Science Office, Code 610, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5561, FAX (301) 614-6530, and is available on the World Wide Web at [eos.nasa.gov/earth\\_observer.php](http://eos.nasa.gov/earth_observer.php) or by writing to the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the calendars should contain location, person to contact, telephone number, and e-mail address. To subscribe to *The Earth Observer*, or to change your mailing address, please call Steve Graham at (301) 614-5561, or send a message to [steven.m.graham.2@gsfc.nasa.gov](mailto:steven.m.graham.2@gsfc.nasa.gov), or write to the address above.

### **The Earth Observer Staff**

Executive Editor: Alan Ward ([award@sesda2.com](mailto:award@sesda2.com))

Technical Editors: Tim Suttles ([tsuttles@bellsouth.net](mailto:tsuttles@bellsouth.net))  
Charlotte Griner ([cgriner@earthlink.net](mailto:cgriner@earthlink.net))

Design, Production: Deborah McLean ([dmclean@sesda2.com](mailto:dmclean@sesda2.com))



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