NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The Earth Observer

Editor's Corner

Michael King
EOS Senior Project Scientist

I am pleased to report that the long-awaited report from the National Academy of Science's Decadal Survey—*Earth Science and Applications: National Imperatives for the Next Decade*—has been released—see *www.nap.edu/catalog/11820.html*. In conducting the survey, seven panels convened to assess the needs in the following areas: Earth science applications and societal needs; land use change, ecosystem dynamics, and biodiversity; weather (including space weather and chemical weather); climate variability and change; water resources and the global hydrologic cycle; human health and security; and solid Earth hazards, resources and dynamics. This approach assured that key disciplines (e.g., oceanography and atmospheric chemistry) were represented across multiple panels, even though their names don't specifically appear in the titles of the panels. Each panel solicited input from the scientific community and got a large amount of responses. The final report synthesizes the findings of all seven panels and calls for an integrated suite of missions that preserves the highest priorities of each panel, and also gives some guidance on how to handle budget or technology development problems.

The survey puts forth a prioritized list of flight missions and supporting activities to support national needs for research and monitoring of the dynamic Earth system during the next decade, and also (to a lesser extent) identifies important directions that should influence planning for the decade beyond. The final report recommends

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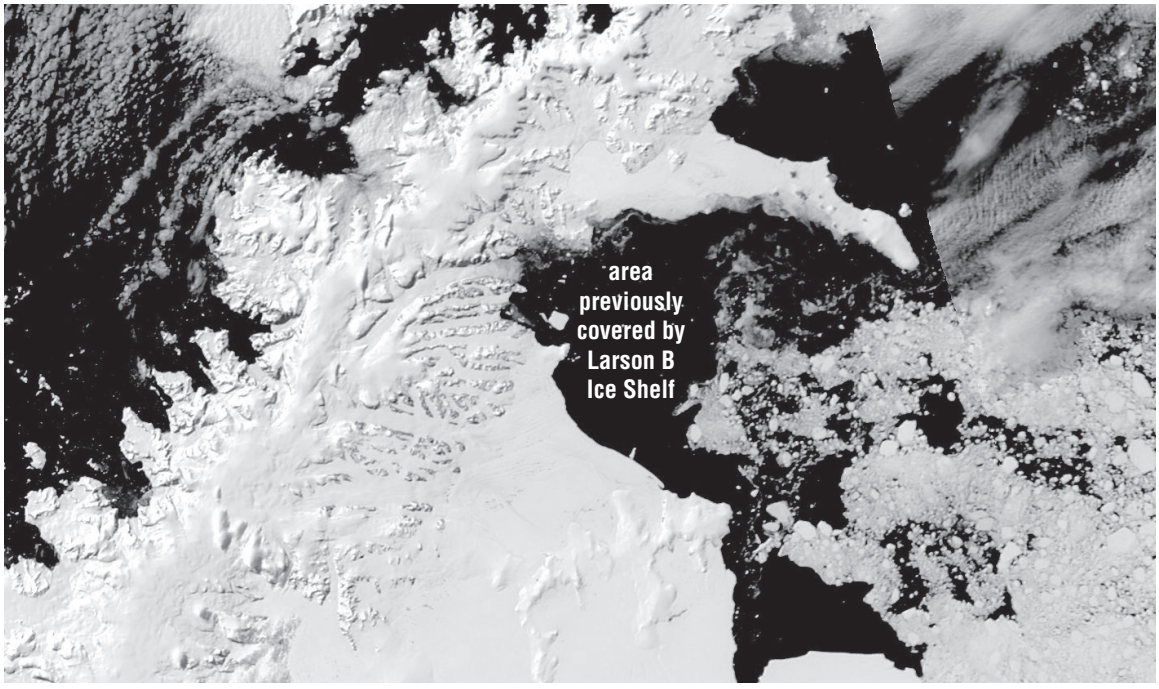


An updated version of the IPCC report was released February 5, 2007. Among the report's conclusions are that humans are making a significant contribution to global climate change. Perhaps nowhere is the increased rate of climate change more evident than in the Polar Regions. A cloud-free afternoon over the Antarctic Peninsula on February 9, 2007, provided this striking image of rugged, snow-covered mountains, glacier-filled valleys, and smooth, broad expanses of ice shelves hanging over the lip of the coastline into the waters of the Southern Ocean. The semi-circular bay at the right side of the image is the area that the Larsen B Ice Shelf occupied for at least 400 years—and possibly as many as 12,000 years—until March 2002. Increasingly warm summers on the Antarctic Peninsula over recent decades caused the huge ice shelf to disintegrate suddenly in March 2002. For more information and color image see: *eobglossary.gsfc.nasa.gov/Newsroom/NewImages/images.php3?img_id=17556*. **Credit:** NASA image courtesy the GSFC MODIS Rapid Response Team.

In This Issue

a path that seeks to restore U.S. leadership in Earth science and applications and avert a potential collapse of the system of environmental satellites. The overarching recommendation is that:

The U.S. government, working in concert with the private sector, academia, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications.

In terms of specific recommendations for NASA, the committee recommends that NASA seek continuity of precipitation and land cover measurements—i.e., launch the Global Precipitation Measurement (GPM) mission and the Landsat Data Continuity Mission (LDCM)—and also seek cost-effective, innovative ways of obtaining land cover change information. Looking toward future missions, the survey calls for NASA (and NOAA) to undertake a set of 17 recommended missions, spread out over the next decade.

An updated version of another major report was released February 5, 2007, from the Intergovernmental Panel on Climate Change (IPCC) titled *Climate Change 2007: The Physical Science Basis*. It is the Working Group I contribution to the IPCC Fourth Assessment Report. This report "describes progress in understanding of the human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future climate change," and includes findings from research that has been done over the past six years. The 18-page *Summary for Policymakers* can be found at: *ipcc-wg1.ucar.edu/wg1/docs/WG1AR4_SPM_Approved_05Feb.pdf*.

I'd also like to report that President Bush has submitted his proposed budget for fiscal year 2008 (FY'08) to Congress. The total proposed budget for NASA is $17.3094 B, up slightly from the fiscal year 2007 (FY'07) budget of $16.7923 B**.** Of that amount **$1.4973 B is slated for Earth Science** for FY'08, just a bit more than the $1.4645 B that Earth Science received in FY'07. The proposed Earth Science budget accounts for approximately 27.1% of the total proposed Science Mission Directorate budget of $5.5161 B for FY'08. Growth in programmatic funding for Science—without regard to changes in full cost allocations—remains at 1% per year from FY'08 through FY'11, and begins to grow by 2.4% thereafter. NASA has placed a priority on completing the International Space Station before the shuttle fleet is retired in 2010, and on developing new human spaceflight systems, that has resulted in a slower rate of growth for Science than previously planned.

In terms of specifics relating to Earth Science, the budget does take into account the conclusions of the *decadal survey* report discussed above, and balances investments based on the priorities and programmatic needs identified in the report. Funding is included to launch the Ocean Surface Topography Mission (OSTM) to measure sea surface heights and the Orbiting Carbon Observatory to conduct a global inventory of carbon dioxide in 2008. The budget also includes continued funding for the development of the GPM/Core and GPM/Constellation spacecraft—target launch dates of 2013 and 2014 respectively—and provides additional funds for the LDCM and Glory missions to stay on schedule.

The *NASA FY 2008 Budget Request Summary* included a message from NASA Administrator **Michael Grif-**

fin that likened the challenge of implementing the President's *vision for space exploration* to the engineering and management challenges faced by the Apollo program, and also reiterated previous statements in support of Science at NASA. (The full text of the statement is available at: *www.nasa.gov/pdf/168653main_NASA_FY08_Budget_Summary.pdf*—page 2.)

I believe that the assembly of the International Space Station is a more difficult engineering feat than was the Apollo program. Certainly, completing the International Space Station, retiring the Space Shuttle by 2010, and managing the effective transition from the Space Shuttle to new commercial cargo and crew transportation capabilities, the Orion Crew Exploration Vehicle, and Ares launch vehicles are the greatest management challenges facing NASA since the Apollo era. ***Science continues to be a high priority at NASA.*** *At this time there are 58 operational NASA spacecraft advancing our scientific understanding of our home planet, the solar system, and the structure and evolution of the universe. Pursuant to the President's recent executive order for our Nation's aeronautics research and development policy, NASA is supporting innovative research leading to significant advances in aeronautical concepts, technologies, and capabilities to advance the United States' technological leadership in aeronautics and to facilitate the educational development of our aeronautics workforce.*

Griffin also testified before the Senate Commerce Subcommittee on Space, Aeronautics and Related Sciences on February 5 and reported on the highlights of the FY'08 budget. The full text of this speech can be viewed at: *www.nasa.gov/pdf/168674main_mg_fy08_budget_rollout.pdf*.

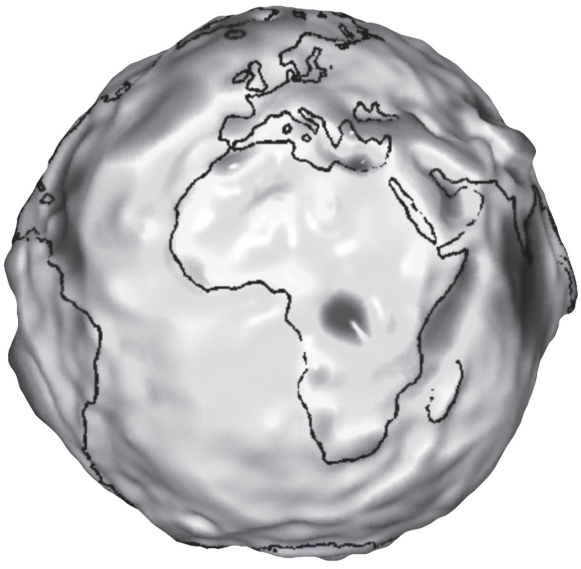
In other news, **Mary Cleave** has announced her retirement from NASA Headquarters. She will be succeeded by **S. Alan Stern** as Associate Administrator of the Science Mission Directorate (SMD) effective April 2. Stern joins NASA from the Southwest Research Institute's Space Science and Engineering Division in Boulder, CO where he served as Executive Director. He is a planetary scientist whose research has focused on studies of the solar system, and he has served on the NASA Advisory Council as principal investigator on a number of planetary and lunar missions. We appreciate Cleave's leadership over the past two years, and wish her the best in her retirement. We would like to welcome Stern to the SMD and look forward to working with him to continue the progress of NASA Earth Science research in the future.

Lastly, the Gravity Recovery and Climate Experiment (GRACE) celebrated the fifth anniversary of its launch on March 17. GRACE was specifically mentioned among the FY'06 highlights for Earth science in the President's FY'08 budget request.

NASA helped increase understanding of the dynamic interactions that take place between Earth's land, oceans, and atmosphere. As part of this effort, scientists obtained better measurements of ice sheets, ocean levels, and the ozone layer using ***the Gravity Recovery and Climate Experiment (GRACE)****, Ice, Cloud, and land Elevation satellite (ICEsat), and other Earth-observing missions.*

Data from GRACE have improved the accuracy of our knowledge of Earth's gravity field by over 100 times, and is living up to its name by revolutionizing our understanding of important aspects of Earth's climate. Monthly averages in the gravity field are being used to detect water storage changes in river basins as small as 300 km radius, ice-mass loss from Greenland and Antarctica, and changes in ocean circulation and heat content. Long-term averages are being used to study changes in mass distribution and their response to global climate change. On behalf of the entire staff of *The Earth Observer*, I'd like to extend my personal congratulations for a job well done to Principal Investigator Byron Tapley, to the entire GRACE Science Team, and to all who are involved with this mission. Keep up the good work and Happy Anniversary! ■

The Gravity Recovery and Climate Experiment (GRACE) celebrated the fifth anniversary of its launch on March 17. This map, created using data from the GRACE mission, reveals variations in the Earth's gravity field. The dark sunken areas show lower than normal gravity, such as the Indian Ocean (far right of image) and the Congo river basin in Africa. Raised areas indicate higher than normal gravity. The long bump protruding from the lower left side of the image indicates the Andes Mountains in South America, while the bump on the upper right side of the image indicates the Himalayan mountains in Asia. For high resolution color image see: *www.csr.utexas.edu/grace/gallery/gravity/*. **Credit:** The University of Texas Center for Space Research as part of a collaborative data analysis effort with the NASA Jet Propulsion Laboratory and the GeoForschungsZentrum in Potsdam, Germany.



Using NASA Research to Teach Science in the *Native Ways of Knowing* Secondary Science Teacher Education Project

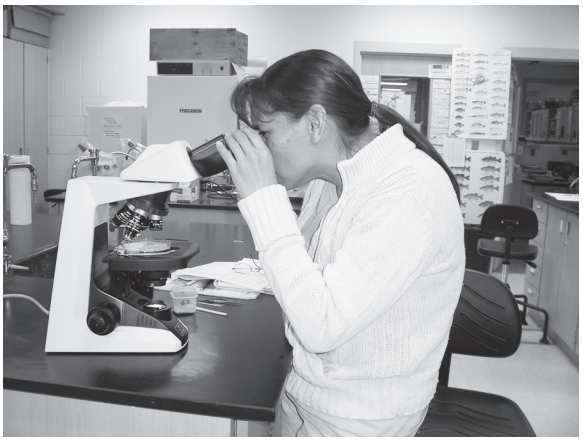
Tibisay Marin, Turtle Mountain Community College, tmarin@tm.edu

National Science Foundation research has shown that increased opportunities for scientific reading and hands-on activities in the K-12 classroom, lead to a more-scientifically literate student at any level of instruction. NASA research data and materials have been integrated into oceanography, planetary studies and other science courses within the *Native Ways of Knowing* Secondary Science Teacher Education Project at Turtle Mountain Community College, Belcourt, ND, since the fall 2006 semester.

The Earth Observing System has provided extensive materials and data to supplement the oceanography course, including data from EOS satellites: Sea-viewing Wide Field of View Sensor (SeaWiFS); Tropical Rainfall Measuring Mission (TRMM); QuikSCAT (SeaWinds); Terra; Aqua; Ice, Clouds, and land Elevation Satellite (ICESat); Aura; CloudSat; Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), TOPEX/Poseidon, and Jason-1. In addition, data from NASA/Jet Propulsion Laboratory's (JPL) Ocean Surface Temperature from Space, NASA's Distributed Active Archive Centers (DAACs), and from NASA Goddard Space Flight Center's Global Change Master Directory have been used. The objective is for students in this project to participate in a curriculum that challenges them to learn beyond the regular textbook and engage in *active learning* in oceanography using scientific readings, and data from research.

Professors and teachers looking at virtual sand lab samples.

One of the highlights of the program is the development of three *virtual labs*. The first of these is the *Sand Lab* where students study characteristics of various sand samples collected from different places in the world. The students then correlate information relative to their global distribution with data gathered from satellites and scientific observations.



Student Coreena Patnude doing the sand lab for oceanography. Patnude is also a pre-service teacher in the *Native Ways of Knowing* Program.

The second virtual lab focuses on coral reefs. Students monitor the state of coral reefs using satellite data to acquire a better understanding of our planet Earth, and the changes coral reefs undergo as human pollution escalates. Students monitor the weather and long-term climate change. In addition, the students investigate the effects of El Niño and La Niña on global patterns of ocean circulation and food distributions through the world's oceans.

The third virtual lab focuses on the impact of oil spills on the marine ecosystem. Students take *virtual trips* to destinations all over the world to "monitor" these oil spills and answer a set of questions related to this

Student Mike Smith examines a sand sample.

Curtis Poitra is a pre-service teacher in the *Native Ways of Knowing* Program.

ecological crisis. Satellite data provide students with a better understanding of these spills, how far they travel, and how the marine ecosystem is affected; this would not be possible without the aid of satellites.

Being able to use these NASA resources provide students with a better understanding of the world's oceans, their dynamics, surface temperatures, and what continues to be a threat to the coral reef ecosystems around the world: coral bleaching and oil spills. These engaging courses would not be possible without the support from NASA Goddard Space Flight Center and the Earth Observing System scientists, and all NASA scientists who share their passion about our planet Earth and beyond.

Beyond the virtual laboratories described above, instructor **Tibisay Marin** and her students visited a number of NASA websites on numerous occasions during an Oceanography and Environmental Science course taught at the college during the Fall 2006 semester.

- The *Visible Earth* site—*visibleearth.nasa.gov*—that showcases Earth imagery from various satellite instruments.

- Feature articles from *The Earth Observatory* site—*earthobservatory.nasa.gov*—that highlight where NASA satellite data has been used to study topics covered in class. Some specific examples include studies that:
  - show the Amazon River Basin is actually "greener" during the dry season than the rainy season—*earthobservatory.nasa.gov/Study/AmazonEVI/*;
  - document the ever-increasing cost of damage caused by natural hazards such as hurricanes—*earthobservatory.nasa.gov/Study/RisingCost/*;
  - reveal the full extent of damage caused by the Sumatra earthquake—*earthobservatory.nasa.gov/Study/Aceh/*;
  - study glaciers from space, documenting their decline and conducting a global inventory—*earthobservatory.nasa.gov/Study/GLIMS/*; and
  - study remote volcanoes—*earthobservatory.nasa.gov/Study/monvoc/*.

- The *NASA Hurricane Resource Reel*—that includes a 1 hour, 15 minute video compilation on hurricanes that showcases a variety of satellite data—*www.nasa.gov/mission_pages/hurricanes/multimedia/mm_gallery.html*.

- The *Terra* website—*terra.nasa.gov*—that gives information on the Terra mission and includes a different "Featured Image" every day.

Marin is very excited about using NASA data in her classroom. She says, "These websites and their contents provide us with a better understanding of planet Earth. At the same time, they are avenues for me to present NASA materials to my students. One of the highlights of my oceanography class this spring is the use of remote sensing in oceanography for tracking sediment load distribution, algae blooming, and the dispersion of oil spills around the world. Two more labs will be done this semester that will have an emphasis on using materials from the Earth Observing System research."

Tibi Marin is a Science Instructor at Turtle Mountain Community College and author of this article.

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JASON XV: Rainforests at the Crossroads—A Teacher Argonaut's Tale

Dianne Forthman, Deepwater Junior High, dforthman@planet-save.com

In the summer of 2004, Dianne Forthmann, a junior high teacher from a suburb of Houston, TX, got the opportunity of a lifetime when she participated in the ***JASON XV: Rainforests at the Crossroads*** *expedition. Recently,* ***The Earth Observer*** *staff contacted Forthmann and asked her if she would share her story with us. What follows is her account of her adventures in Panama.*

My name is **Dianne Forthmann**, and I work at Deepwater Junior High in Deer Park ISD, which is a suburb of Houston, Texas. I teach Technology Education to sixth, seventh, and eighth grade students. My classroom is a Synergistic's Lab that involves students working at 18 workstations, with subjects ranging from Rocket Science to Forensic Science, Interior Design, Robots, and Digital Video. It is a very stimulating, hands-on learning environment. I want to tell you the story of how a teacher from Texas became a Jason Teacher Argonaut.

Some important events in life seem to come about by happenstance, and that was how my involvement with the JASON Project began. I wasn't really seeking out this opportunity at first. A teacher, who knew me well, brought a letter to me. She said she had received the letter, but that it sounded like something I would be more interested in than she. To be honest, at first, the letter was rather confusing, not making it clear what the intent or purpose was. However, talk of grey whales, the Sea of Cortez, and deep-sea vents peaked my curiosity. How could I not want to find out more?! I did some research, and learned about the JASON Project and attended a teacher-training day at Johnson Space Center in Houston. By the end of the day, I knew this was an opportunity I wanted to share with my students.

Since my first exposure to the program in 1993, I have continued to participate in the JASON Project, sharing the project with students in my classroom and with an environmental club I co-sponsored. A highlight was when one of my students applied for and was selected as a JASON Project *Student Argonaut* for JASON X*: Rainforests—A Wet and Wild Adventure*. The student traveled to Peru, where she had an opportunity to study the tropical rainforests, and compare them with temperate rainforests. This was a life changing adventure for this student, helping her gain self-esteem and confidence.

After years of encouraging students to apply for the Argonaut position, I was inspired to apply for this unique opportunity myself. When I learned that JASON XV would be traveling to the rainforests of Panama in 2004, I knew that was the expedition for me. You see, I had spent time studying the rainforest in Ecuador and volunteering in the rainforests of Mauritius, and so naturally I wanted to learn more about this fascinating part of our world.

After months of wondering if I made the JASON XV team of argonauts, I received word that I had been selected. Yeah! Time to celebrate, right? Hardly. More like, time to get to work!

Almost as soon as we were told we made it, we were given our first assignment—no time to bask in the glory! *Teacher Argonauts* are involved in the process of selecting the *Student Argonauts* for each expedition, so within days of becoming a *Teacher Argonaut*, I was pouring over student applications and conducting phone interviews. Knowing first hand the importance of this expedition and what an impact it can make on a student's future, I took the responsibility very seriously and it was difficult for me. Probably, each of the applicants would have been a wonderful Argo, but we could only choose 24—tough job.

Teacher Argos with Astronauts Sunita Williams and Peggy Whitson at the Neutral Buoyance Laboratory.

Teacher Argos in the Apollo Mission Control room during their 2006 visit to NASA Johnson Space Center in Houston, TX.

In addition to selecting *Student Argonauts*, *Teacher Argonauts* attend the National Education Conference in Milwaukee, WS. This is a week-long event, where we received our first exposure to the curriculum for JASON XV: *Rainforest at the Crossroads*, which we would be teaching to students in our classrooms and also guiding the *Student Argonauts* through. In addition to attending the conference sessions, we sailed on Lake Michigan, took a riverboat tour through Milwaukee, and most importantly became acquainted with the other *Teacher Argonauts*. Spending every waking moment with each other provided ample time to realize we were a unique group who thrived on each other's company. By the end of the week, all of us felt a connection with each other and were already looking forward to the time we would reunite in Panama.

Although the actual JASON Expedition lasted only two weeks, the entire school year focused on the project. I introduced the curriculum to faculty at my school, taught it to students in my classroom, and monitored the progress and preparation of three *Student Argonauts* through e-mail and conference calls. In addition, I organized a school-wide, 600-student, field trip to attend one live broadcast at Johnson Space Center. (I am fortunate to work in an incredibly supportive school and district.) The other faculty increased excitement and interest in the project by reading JASON novels in language arts classes and monitoring the weather on Barro Colorado Island in science classes. The school also held an assembly, honoring my personal and professional accomplishments. It was this excitement and involvement of my family, faculty, and students that made the JASON experience so meaningful for me.

Once in Panama, both *Teacher Argonauts* and *Student Argonauts* were divided into two groups, with most students going to study and stay on Barro Colorado Island, a world-renowned research station, run by the Smithsonian Tropical Research Institute (STRI). Another teacher, two students, and I, however, stayed on the mainland in Gamboa, Panama. Our little group was known as *The Rovers*, and our activities were filmed for the broadcast as opposed to the group on the island having their work shown live. A highlight of our time together was being on a canal tug as it pushed an ocean going freighter into a lock of the Panama Canal—see top photo below. I am a sailor, so I could appreciate the precision it took to place a 106-feet wide ship into a 110-feet wide lock. The *Rovers* also visited Centro SIDMAR, where ship captains are trained to navigate the Panama Canal. While we were there, we participated in a simulation.

Once the filming was complete, we joined the live broadcast on Barro Colorado Island, assisting the JASON research scientists. I feel that as a *Rover* I had the best of both worlds, exploring the mainland, yet also having time on the captivating Barro Colorado Island—see bottom photo below.

We were busy from before sunrise until late night, and it seemed the time passed all too rapidly. Before we knew it, it was time to return to the U.S.

Looking back on the JASON experience, two things stand out to me: the opportunity to work with world-renowned

A Panama Canal tug navigates the Mira Flores Lock.

Dianne Forthmann observing leaf cutter ants on Barro Colorado Island.

scientists in an environment I find fascinating and the camaraderie developed among the *Argonauts*. Fortunately, both of these have continued to play a part in my life.

Years ago, I began using my summer vacations to pursue my passion for environmental work, and the contacts I made at the STRI during the JASON Expedition have provided continued summer adventures. My young daughters and I have spent two summers volunteering with STRI scientists, one working on a butterfly project and the other on a bird project.

The other aspect, the unique camaraderie among the *Argos*, remains a meaningful part of my life. Even with busy schedules, we have stayed in touch and had yearly reunions. A highlight of these reunions was when six *Teacher Argonauts* came to Texas to celebrate my fiftieth birthday. NASA provided the climax of the trip with an insider's tour of Johnson Space Center—see photos on previous pages. The *Student Argonauts* also continue to correspond with e-mails of their accomplishments and endeavors, making me proud to know these young people. On occasion, we are fortunate enough to have our paths cross, strengthening our bond with these exceptional students. ■

KUDOS

The American Meteorological Society (AMS) named the following EOS colleagues as award winners at their recent annual meeting in San Antonio, TX.

The Verner E. Suomi Award
Yoram J. Kaufman (deceased), NASA Goddard Space Flight Center (GSFC), "For fundamental contributions to remote sensing of aerosols and for outstanding contributions to aerosol climate forcing research."

The Charles Franklin Brooks Award for Outstanding Services to the Society
Warren M. Washington, National Center for Atmospheric Research, "For decades of service to the AMS and as a representative of the atmospheric sciences community at the highest levels of policymakers."

The Clarence Leroy Meisinger Award
Amy C. Clement, University of Miami, "For her insightful advances in understanding the role of the tropical ocean-atmosphere system in past climate variations."

Journal of Hydrometeorology Editor's Award
Randal Koster, NASA GSFC, "For timely, comprehensive and constructive reviews, benefiting the authors and the journal."

The following were named ***AMS Fellows***. "The honor of Fellow is given to an individual for recognition of outstanding contributions to the atmospheric or related oceanic or hydrologic sciences, or their applications, during a substantial period of years. Only two-tenths of 1% of membership are approved as Fellows each year."

Randal D. Koster, NASA GSFC
W. Paul Menzel, University of Wisconsin, Madision
Michael I. Mishchenko, NASA Goddard Institute for Space Studies
Richard W. Reynolds, NCDC/NESDIS/NOAA, Asheville, NC

The Earth Observer staff would like to join the entire scientific community in congratulating these individuals on their outstanding accomplishments.

National Snow and Ice Data Center Contributes to Climate Change Report

Stephanie Renfrow, National Snow and Ice Data Center, srenfrow@nsidc.org

NASA scientists around the nation were among the thousands of scientists, worldwide, who contributed to a February 2, 2007, United Nations report on climate change. They agree that global warming is not only happening, but that humanity is the cause. The first section of the report, *Climate Change 2007: The Physical Science Basis*, addresses the causes, observations, and future projections of climate change.

Among the NASA scientists who contributed to the report were experts from the National Snow and Ice Data Center (NSIDC) at the University of Colorado at Boulder. NSIDC scientists provided data for figures, wrote text, and reviewed content for the report, primarily for Chapter 4, *Observations: Changes in Snow, Ice and Frozen Ground*.

NSIDC Senior Scientist **Tingun Zhang** was a lead author for Chapter 4. He wrote much of the *Changes in Frozen Ground* section and helped develop several summary figures. "The report took more than two years to develop," he said. "Many of us spent months, over the two years, working to provide accurate content in our fields of expertise."

NSIDC Director **Roger Barry** also played an important role in Chapter 4, providing his 30 years of expertise in polar and alpine climates as a Review Editor. "The changes we are seeing in the cold regions of the planet have accelerated dramatically in the past decade," he said.

Other NSIDC contributors included **Oliver Frauenfeld**, **Bruce Raup**, **Andrew Slater**, and **Walt Meier**, who was interviewed for several local and international television and radio broadcasts,

To download a PDF of the Intergovernmental Panel on Climate Change Report's Executive Summary, go to *www.ipcc.ch/SPM2feb07.pdf*. For more information on NSIDC's involvement in *Climate Change 2007: The Physical Science Basis*, please contact **Stephanie Renfrow** at *srenfrow@nsidc.org*.

On the left is a photograph of Muir Glacier taken on August 13, 1941, by glaciologist William O. Field; on the right, a photograph taken from the same vantage point on August 31, 2004, by geologist Bruce F. Molnia of the United States Geological Survey (USGS). According to Molnia, between 1941 and 2004 the glacier retreated more than 12 km (7 mi) and thinned by more than 800 m (875 yds). Ocean water has filled the valley, replacing the ice of Muir Glacier; the end of the glacier has retreated out of the field of view. The glacier's absence reveals scars where glacier ice once scraped high up against the hillside. In 2004, trees and shrubs grow thickly in the foreground, where in 1941 there was only bare rock. **Credit:** National Snow and Ice Data Center, W. O. Field, B. F. Molnia

Summary of the Landsat Science Team Meeting

Thomas R. Loveland, U.S. Geological Survey Center for Earth Resources Observation and Science, Loveland@usgs.gov
James R. Irons, NASA Goddard Space Flight Center, James.R.Irons@nasa.gov

Meeting Overview

The first meeting of the United States Geological Survey (USGS) and the NASA Landsat Science Team was held January 9-11, 2007, at the USGS Center for Earth Resources Observation and Science (EROS) near Sioux Falls, SD. The Landsat Science Team, funded by the USGS, was established to advance the objectives of the NASA-USGS Landsat Data Continuity Mission (LDCM), and to contribute to the complete integration of LDCM data with past, present, and future Landsat and other remotely sensed data for the purpose of observing and monitoring global environmental systems. The Landsat record, beginning in July 1972, is already the longest and most comprehensive unbroken collection of global land observations in existence. With LDCM, the Landsat legacy will become a nearly 45-year global land record. The uniqueness and value of this record places additional responsibilities on the LDCM design. The Landsat Science Team will provide the science support needed by the USGS and NASA on issues critical to the success of the mission, including data acquisition, product access and format, and science opportunities for new- and past-generation Landsat data.

The Landsat Science Team consists of 18 members selected through a competitive process. The Principal Investigators (PI's), their affiliation, and research focus are listed in **Table 1**.

Technical Presentations Summary

Meeting objectives, offered by **Tom Loveland** [USGS—*Landsat Project Scientist*], included:

- a review of LDCM and Landsats 5 and 7 status and plans;
- a review of related activities relevant to Landsat data continuity and Earth observation and monitoring;
- an introduction to the science activities of the Landsat Science Team members; and
- identification of team priorities and working strategies.

The meeting agenda and presentations are available at *ldcm.usgs.gov/intro.html*.

R. J. Thompson [USGS—*EROS Director*], **Bruce Quirk** [USGS—*Acting Land Remote Sensing Program Coordinator*], and **Ed Grigsby** [NASA Headquarters—*Landsat Program Executive*] each provided their perspectives on the importance of the Landsat Science Team in meeting the goals of the LDCM mission. They emphasized that the key to the initial meeting was to establish a dialog between the Landsat Science Team and NASA and USGS developers. They surmised that the USGS, NASA, and the Landsat Science Team together are essential to mission success.

Bill Ochs [NASA Goddard Space Flight Center (GSFC)—*LDCM Project Manager*] provided a status report on where the project has been, where it is today, and where it is going. In 1999, plans were initiated for a commercial data buy as the mechanism to ensure Landsat data continuity. Unfortunately, in 2003, the solicitation was canceled due to unresolvable problems with the proposed government-industry partnership. In 2004, the Office of Science and Technology Policy (OSTP) issued a memorandum that called for placement of a Landsat-class instrument on the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) platform. By late-2005, it was clear that this configuration was not appropriate and OSTP issued a new memorandum calling for a free-flying LDCM. An LDCM operations concept has been established in which NASA will develop the launch and space segments and the USGS will develop the flight operations and data processing and archive segments.

Ochs informed the team that the Request for Proposals for the Operational Land Imager (OLI), the next generation sensor, was released on January 9, 2007 with responses due to NASA on February 23, 2007. An instrument award is expected in early summer. The OLI is a multispectral, moderate resolution (30 m) sensor capable of providing an average of 400 scenes (185 km x 180 km) per day to the archive—see **Table 2**. The OLI will not have thermal capabilities but discussions are still ongoing about adding two thermal channels via a stand-alone instrument.

Ochs also explained plans to use the Rapid Spacecraft Development Office Rapid II Catalog for acquiring the LDCM spacecraft. The spacecraft component of the mission is to be contracted by late-2007. The targeted launch readiness date is July 2011.

Mike Headley [USGS—*LDCM Project Manager*] gave an overview of EROS, Landsat support, and LDCM development activities. The USGS is responsible for acquiring and operating the LDCM ground network, data archive, processing and distribution systems, and the data collection scheduling capabilities. The USGS will operate the LDCM observatory following on-orbit

Table 1. Landsat Science Team PI's, affiliation, and research interests.

Principal Investigator	Organization	Research Topic
Richard Allen	University of Idaho	Operational Evapotranspiration Algorithms for LDCM as a Member of the Landsat Data Continuity Mission Science Team
Martha Anderson	USDA Agricultural Research Service	Mapping Drought and Evapotranspiration at High Spatial Resolution Using Landsat Thermal and Surface Reflectance Band Imagery
Alan Belward	European Commission Joint Research Centre	Natural Resources Management—Meeting Millennium Development Goals
Robert Bindschadler	NASA Goddard	Advancing Ice Sheet Research with the Next Generation Landsat Sensor
Warren Cohen	USDA Forest Service	Landsat and Vegetation Change: Towards 50 Years of Observation and Characterization
Feng Gao	Earth Resources Technology	Developing a Consistent Landsat Data Set from MSS, TM/ETM+ and International Sources for Land Cover Change Detection
Sam Goward	University of Maryland	The LDCM Long Term Acquisition Plan: Extending and Enhancing the Landsat 7 LTAP Approach
Dennis Helder	South Dakota State University	A Systematic Radiometric Calibration Approach for LDCM and the Landsat Archive
Eileen Helmer	USDA Forest Service	Cloud-Free Landsat Image Mosaics for Monitoring Tropical Forest Ecosystems
Rama Nemani	NASA Ames	Developing Biophysical Products for Landsat
Lazaros Oraiopoulos	University of Maryland Baltimore County	Cloud Detection and Avoidance for the Landsat Data Continuity Mission
John Schott	Rochester Institute of Technology	The Impact of Land Processes on Fresh and Coastal Waters
Prasad Thenkabail	International Water Management Institute	Global Irrigated Area Mapping using Landsat 30-m for the Years 2000 and 1975
Eric Vermote	University of Maryland	A Surface Reflectance Standard Product for LDCM and Supporting Activities
Jim Vogelmann	USGS EROS/SAIC	Monitoring Forest and Rangeland Change Using Landsat Continuity and Alternative Sources of Satellite Data
Curtis Woodcock	Boston University	Toward Operational Global Monitoring of Landcover Change
Mike Wulder	Canadian Forest Service	Large-Area Land Cover Mapping and Dynamics: Landsat Imagery to Information
Randy Wynne	Virginia Tech	Commercial Forestry Applications of Landsat and LDCM Data

acceptance and for the life of the mission. Headley also explained the major requirements of the LDCM ground system, including:

- perform mission operations including data collection scheduling;
- ingesting and archiving 400 World Reference System-2 (WRS-2) scenes per day;
- making data available for search and ordering within 24 hours following acquisition;
- providing standard orthorectified data products within 24 hours of collection and making the standard products accessible via the web at no cost;
- providing "user specified" data products; and
- ensuring that LDCM data are calibrated consistently with data from previous Landsat missions.

Table 2. OLI spectral and ground resolution specifications

#	Band	Minimum Lower Band Edge (nm)	Minimum Lower Band Edge (nm)	Center Wavelength (nm)	Maximum Spatial Resolution at Nadir (m)
1	Coastal/Aerosol	433	453	443	30
2	Blue	450	515	482	30
3	Green	525	600	562	30
4	Red	630	680	655	30
5	NIR	845	885	865	30
6	SWIR 1	1560	1660	1610	30
7	SWIR 2	2100	2300	2200	30
8	Panchromatic	500	680	590	15
9	Cirrus	1360	1390	1375	30
10*	Thermal 1	10300	11300	10800	120
11*	Thermal 2	11500	12500	12000	120

* Provision of thermal capabilities is contingent upon requirement trades between program elements, technical requirements, and mission risk as part of the LDCM procurement.

Jim Irons [GSFC—*LDCM Project Scientist*] provided additional history on the evolution of LDCM, outlined the LDCM Programmatic and Level 1 Requirements, and emphasized the importance of Landsat data continuity, and the significance of Landsat 7 as a benchmark with respect to instrument data characterization and calibration. Irons also reviewed the needs and issues facing the addition of a thermal imaging system on the LDCM platform. Finally, Irons and **Jason Williams** [USGS/Scientific Applications International Corporation (SAIC) walked the team through the technical details of the mission operations concept.

In the final LDCM presentation, **John Dwyer** [USGS/SAIC—*LDCM Principal Scientist*] shared the current plans for standard and user-specified data products. Standard product specifications include: (1) Level 1 Systematic Terrain Corrected Landsat Data (L1Gt) product generated routinely and based on a fixed recipe; (2) geolocation accuracy achieved using definitive ephemeris; (3) relief displacement corrected using best available digital elevation models; and (4) web-enabled access for electronic retrieval. User-specified products are defined as products generated on-demand by user request. Dwyer said that input is needed from the user community on the levels of processing and service that are required.

Kristi Kline [USGS—*Landsat Project Manager*] provided an overview of the status and plans for Landsat 5 and 7 operations. Launched in 1984, Landsat 5 continues to acquire data. Engineering solutions to solar array drive malfunctions and X-band transmission problems have enabled continued operation. Other than the scan line corrector (SLC) failure in May 2003, Landsat 7 is fully functional and acquiring global data.

Rachel Kurtz [USGS—*Acting Landsat Acquisitions Manager*] presented an overview of upcoming Landsat 7 SLC-off, gap-filling products that are based on new segmentation methods. In addition, she described USGS plans to make contemporary terrain corrected conterminous U.S. Landsat 7 SLC-off data available via the web at no cost starting in March 2007.

Ron Hayes [USGS/SAIC] and **Brian Markham** [GSFC] presented efforts to maintain current and consistent Landsat 5 and 7 calibration documentation, and plans to establish consistent calibration between all Landsat instruments.

Following the presentations on LDCM and Landsat status, discussions turned to related Earth observation topics. **Ray Byrnes** and **John Cullen** [USGS], and **Ed Grigsby** presented an overview of the Future of Land Imaging (FLI) activities. They reported that the following statement is the outcome of the OSTP-led FLI planning process:

> *"It is proposed that the U.S. establish a National Land Imaging Program led by the U.S. Department of the Interior to ensure U.S. leadership in all areas of civil land imaging and land science, including the development and operation of all U.S.-owned operational space assets dedicated to civil land imaging purposes, and that the U.S. pursue a strategy of collaborating with its international partners and other U.S. and foreign commercial entities to augment U.S. capabilities to the level required to meet U.S. operational needs."*

Because the forthcoming FLI report will have considerable influence on the future of moderate resolution

Earth observation, the Landsat Science Team plans to become active in the next stage of FLI planning.

Jeff Masek [GSFC] presented an overview and status of the Mid-Decadal Global Land Survey activities. This project will provide a consistently processed 2004-2006 moderate resolution global image database comprised primarily of Landsats 5 and 7 scenes. This effort adds to the 1990 and 2000 Geocover Landsat global coverage and is designed to meet Climate Change Science Program science objectives as well as the many other needs for regional to global environmental assessments. Masek also presented an overview of the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) developed in support of forest disturbance mapping as part of North America Carbon Program investigations. LEDAPS provides a testbed for testing product characteristics in the LDCM era.

It seems likely that Landsats 5 and 7 will both cease operations prior to the launch of LDCM. **Gregg Stensaas** [USGS] and **Gyanesh Chander** [USGS/SAIC] presented an overview of the NASA-USGS Landsat Data Gap data characterization studies that are underway. Data gap planning is designed to identify those moderate resolution missions—e.g., **China/Brazil**—China-Brazil Earth Resource Satellite (CBERS-2); **India**—Indian Remote Sensing Satellite (IRS) Advanced Wide Field Sensor (AWifs), Low Imaging Sensing Satellite (LISS III and IV)—that can be combined to provide continued global coverage until LDCM is operational. The formulation and implementation of a data gap strategy is still pending until a number of policy issues are resolved.

Finally, each Landsat Science Team PI gave a brief presentation on their research plans that relate to LDCM and Landsat. The presentations (*ldcm.usgs.gov/scienceP-resentation.html*) addressed product, calibration/validation, and applications topics.

Meeting Conclusions

On the final day of the meeting, the Landsat Science Team members focused on organizational issues and laid plans for future team activities. The topics included team leadership, working groups, and study issues that must be addressed at the next meeting.

The Landsat Science Team leadership structure was clarified and the broad duties of the leadership team were defined. The team is led by two co-chairs, **Tom Loveland** (USGS) and **Jim Irons** (NASA). Their responsibilities include facilitating the functions of the team and recommending the team's agenda and priorities. The third member of the science team leadership group is the Landsat Science Team Leader. The Team Leader is elected from the ranks of the team members, with responsibilities including serving as the lead representative of the Landsat Science Team, acting as a spokesperson for the team, and communicating team needs to the USGS and NASA. **Curtis Woodcock** [Boston University] was elected by the other 17 science team members to serve as the Team Leader.

The team established four working groups that will work with USGS and NASA staff to address a set of Landsat and LDCM mission topics. The working groups, working group coordinators, and example topics are:

- *Operations Acquisition Strategy* (Darrel Williams, GSFC) – Long-term acquisition program; international cooperators; and off-nadir acquisition issues
- *Products, including archive data* (John Dwyer, USGS/SAIC; Jeff Masek, GSFC) - Data gap, mid-decadal studies; quality assurance and validation; monitoring sciences and applications development; user models; data and measurement continuity (i.e., Climate Data Records); surface reflectance, atmospheric corrections; and thermal data needs.
- *Future Missions, Outreach and Advocacy* (Sam Goward, University of Maryland College Park) – FLI and long-term observation needs; international cooperation; thermal data advocacy.
- *Instrument Engineering* (Dennis Helder, South Dakota State University) – calibration; observation technologies; and surface reflectance, atmospheric corrections, etc.

The first action taken by the working groups was the preparation of a letter to NASA, USGS, and other organizations from the Landsat Science Team advocating for a LDCM thermal infrared imaging system.

The Landsat Science Team identified a set of specific topics for study prior to the next meeting. The study results will be reviewed at the next meeting. The questions that are to be investigated and the study lead for each topic include:

- *Mission operations* – What are the key operations issues affecting the acquisition strategy, such as the role of international cooperators, impacts of off-nadir acquisition, Long-Term Acquisition Plan (LTAP), etc.?
- *Future of Land Imaging* – How can the science team express their support of FLI while emphasizing the necessity to include science, applications, and other end-user perspectives into the planning process?
- *USGS Landsat data distribution* – What is the USGS vision and what are the policy plans for distribution of past, present, and future Landsat data?

- *Data gap mitigation implementation* – With a data gap possible any time, what are the specific implementation plans and how will the implementation plans be expedited if a data gap begins sooner than expected?
- *International cooperator historical holdings* – While the international ground stations hold significant amounts of historical Landsat data, the long-term viability of those data could, in some cases, be in jeopardy. In addition, the international holdings represent an invaluable collection needed by the science and applications user community. What is the possibility for expanding the National Satellite Land Remote Sensing Data Archive (NSLRSDA) archive with Landsat data from international cooperator holdings?

The next meeting will be held this coming summer in Corvallis, OR and will be hosted by Warren Cohen of the U.S. Forest Service. ■

Shown here is a Landsat image of Tianjin, China obtained March 6, 2000. This image is one of 77 such images of cities around the world that have been published as part of a new website—*sedac.ciesin.org/ulandsat/*—created by the Socioeconomic Data and Application Center (SEDAC). SEDAC has established criteria to help distinguish urban and land surfaces from other land cover types—by studying reflectance (visible and infrared) and surface temperature differences between urban and non-urban areas. These spatial characterizations of urban land cover extent can be fed into climate, hydrology, and ecology models helping to make the models more accurate. As described on the Urban Landsat web page, Landsat data provide "objective physically-based metrics for comparative analyses of urban dynamics that cannot generally be obtained from administrative definitions of urban extent." SEDAC is a NASA Distributed Active Archive Center (DAAC) that focuses on data about human interactions with the environment. The center is housed at Columbia University's Lamont-Doherty Earth Observatory in New York. **Image Credit:** NASA/SEDAC

Earth Science Highlights from Fall AGU Meeting

Charlotte Griner, NASA Goddard Space Flight Center, clgriner@earthlink.net
Alan Ward, NASA Goddard Space Flight Center, award@sesda2.com

The American Geophysical Union (AGU) held its annual Fall meeting in San Francisco December 11-15, 2006. This was the largest AGU meeting ever; approximately 13,000 attended the meeting. There were hundreds of sessions held throughout the week and many of the sessions focused on Earth-science-related topics. ***The Earth Observer*** *staff identified some sessions that we felt would be of interest to our readers and contacted the session convenors and asked them to contribute summaries. The following article is a synthesis of the information we received.*

Deep Convection, Lightning, and Atmospheric Chemistry

Co-convenors*: Kenneth Pickering [NASA Goddard Space Flight Center (GSFC)]; Chris Cantrell [National Center for Atmospheric Research (NCAR)]; Pierre Laroche [Office National d'Etudes et de Recherches Aérospatiales (ONERA), France]; Heidi Huntrieser [Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany]*

Summary: Kenneth Pickering [GSFC] co-convened two sessions covering aspects of the effects of deep convection and lightning on atmospheric chemistry. The oral session consisted of six invited talks, and a poster session—held jointly with the Thunderstorms and Climate Section—that included eight posters focusing on lightning and atmospheric chemistry.

Three of the talks highlighted recent European-sponsored deep convection, lightning and chemistry field experiments:

- **Francesco Cairo** [Istituto di Scienze dell'Atmosfera e del Clima (ISAC), Italy] discussed the African Monsoon Multidisciplinary Analysis (AMMA) Special Observing Period of 2006 in West Africa.
- **Ken Pickering** presented a talk on behalf of **Geraint Vaughan** [University of Manchester, U.K.] on the Aerosols and Chemical Transport in Tropical Convection (ACTIVE) experiment in Darwin, Australia.
- **Ulrich Schumann** [DLR] discussed the Tropical Convection, Cirrus, and Nitrogen Oxides (TROCCINOX) experiment in Brazil.

Vaughan Phillips [University of Hawaii] explored the connections between aerosol concentration, updraft speed and convective outflow in simulations of thunderstorms from the NASA Cirrus Regional Study of Tropical Anvils in Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) field project in South Florida.

Owen Cooper [University of Colorado] demonstrated the effects of lightning nitric oxide (NO) production on upper tropospheric ozone enhancement during the NASA INTEX-NA field experiment over eastern North America.

Ken Pickering summarized the results of several cloud-resolved mid-latitude and subtropical storm and chemistry simulations aimed at deducing the amount of NO produced on average by cloud-to-ground and intracloud lightning flashes and the effective vertical profile of lightning-induced oxides of nitrogen (NO_x) at the end of the storms. The results of such simulations and the new field experiments will provide information that will lead to better representation of the lightning NO source in global chemical models.

Poster Topic	Presenter(s) [Affiliation]
Lightning NO production estimates from cloud electrification models	**Christine Barthe** [Laboratoire d'Aerologie—Toulouse, France] **Kelly Malone** [South Dakota School of Mines and Technology]
Lightning NO production in controlled experiments	**Mahbubur Rahman** [Angstrom Laboratory—Uppsala, Sweden] **Harold Peterson** [Desert Research Institute]
Representation of lightning NO_x in global atmospheric chemical models	**Brice Barret** [Laboratoire d'Aerologie—Toulouse, France] **Holger Tost** [Max-Planck Institute for Chemistry—Mainz, Germany]
Observations of convective transport of trace gases into the lower stratosphere	**Suraiya Ahmad** [Goddard Space Flight Center]
The Deep Convective Clouds and Chemistry (DC3) field experiment planned for Summer 2010 over the central U.S.	**Mary Barth** [National Center for Atmospheric Research]

Full abstracts of the invited talks can be found at *www.agu.org/meetings/fm06/fm06-sessions/fm06_AE51B.html* and for the poster session at *www.agu.org/meetings/fm06/fm06-sessions/fm06_AE53A.html.*

On the Life of a Black Carbon Particle

***Convenor**: Dorothy Koch [Columbia University]*

Summary: In order to assess the impacts of absorbing carbonaceous particles on climate, we need to improve our understanding of the quantity, quality and impacts on climate of these particles. Thus, this session included presentations on uncertainties in carbonaceous aerosol emissions, model parameterizations and simulations, measurements of concentrations and optical properties, and policy implications.

Emissions

- **Mark Flanner** [University of California, Irvine] discussed results of a model study that suggested that model climate simulations depend upon accurate emissions of black carbon (BC). The findings appear consistent with other model studies.
- **Dorothy Koch** reported on a study that suggested that models also require estimates of supermicron particle emissions since these particles will impact comparison of models with local measurements.
- **Tami Bond** [University of Illinois at Urbana-Champaign] presented some of the complications of emissions estimates, showing that particle characteristics depend on source type; that even similar source types—e.g. woodstoves—in different regions can produce differing particle amounts and that a source in the laboratory generates different emissions than a source in the field.
- **Akinori Ito** [National Institute for Environmental Studies, Japan] showed how biomass burning emission seasonality depends upon fuel combustibility.

Model Treatments

Even when similar emissions are put into different models, the results can differ greatly.

- **Dorothy Koch** showed that models have a large range of absorption optical thickness, generally less than retrieved from the Aerosol Robotic Network (AERONET).
- **Philip Stier** [California Institute of Technology] showed that the radiative forcing of different models per amount of absorption was an even greater source of uncertainty than absorption optical thickness.

Measurements

- **Stephen Warren** [University of Washington] discussed the difficulties of grain size, snow depth, impurities, sun angle, etc. in measuring the effect of black carbon particles (BC) on Arctic snow albedo.
- **Pat Arnott** [University of Nevada, Reno] showed that aging of some biomass burning particles under humid conditions involves collapse, water uptake, increased scattering, and decreased absorption, providing insight into how such particles age.
- **Ryan Spackman** [NOAA Earth System Research Laboratory] presented aircraft BC measurements over Costa Rica and Houston that demonstrated remarkably constant BC amounts—about 1-2 ng/kg—in the mid-upper troposphere, a challenge to be matched by models.
- **Anthony Clarke** [University of Hawaii] demonstrated their efforts to detangle pollution and biomass burning aerosols in International Chemical Transport Experiment (INTEX) measurements, based on their chemical and optical characteristics.
- **Liaquat Husain** [State University of New York at Albany] presented historical carbonaceous aerosol observations that were obtained from lake sediments in New York, a promising new approach for deriving historical BC.

Climate Effects

Several studies were on indirect and semi-direct effects of BC on climate.

- **Paul DeMott** [Colorado State University] presented laboratory data demonstrating that, contrary to what has often been previously speculated, black carbon does not appear to play an important role in ice nucleation.
- **Chien Wang** [Massachusetts Institute of Technology] presented climate model results showing non-local impacts of black carbon on tropical convection.
- **Masa Yoshimori** [Rutgers University] also demonstrated non-local impacts of BC on climate, including reductions of precipitation and shifts of the storm tracks.
- **Mark Flanner** presented model results for impacts of black carbon on snow melting, estimating the impact to be potentially quite large during spring-summer, enhancing melt, and decreasing air temperatures.

Policy Implications

Considering these uncertainties, how should BC be incorporated into climate-related policy discussions?

- **Ben DeAngelo** [U.S. Environmental Protection Agency] suggested that the combined effects of BC on climate and contributions to the *PM2.5* pollution are large enough to justify work on mitigation strategies and to calculate cost benefits.
- **Terje Berntsen** [Center for International Climate and Environmental Research, Norway] suggested

using an *Integrated Global Temperature Potential* metric to compare the impacts of BC and carbon dioxide (CO_2).

Full abstracts of these and other presentations are located at *www.agu.org/meetings/fm06/fm06-sessions/fm06_A33G.html*, *…A34C.html*, and *…A43A.html*.

Thermal Remote Sensing Data for Earth Science Research: The Critical Need for Continued Data Collection and Development of Future Thermal Satellite Sensors

Co-convenors: *Dale A. Quattrochi; Jeffrey C. Luvall [NASA Marshall Space Flight Center (MSFC)]; Simon J. Hook [Jet Propulsion Laboratory]; Martha Anderson [U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) Hydrology and Remote Sensing Laboratory]*

Summary: There is a rich and long history of thermal infrared (TIR) remote sensing data for multidisciplinary Earth science research. The continuity of TIR data collection, however, is now in jeopardy given there are no planned future Earth observing TIR remote sensing satellite systems with moderately high spatial resolutions to replace those currently in orbit on NASA's Terra suite of sensors. This session brought together researchers who have actively worked in the field of TIR remote sensing to present results that elucidate the importance of thermal remote sensing to the wider Earth science research community. Additionally, this session provided a forum for presenting concepts and ideas for new thermal sensing systems with high spatial resolutions for future Earth science satellite missions, as opposed to systems such as the Visible/Infrared Imager/Radiometer (VIIRS) suite of sensors scheduled for launch on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) in 2009, and the TIR instrument currently onboard the ASTER satellite that collects TIR data at coarse spatial resolutions.

This session was part of the AGU Hydrology Section of oral presentations and posters. The session was comprised of two oral sessions and one poster session. In all, there were 14 oral presentations and 15 posters that comprised the session. There was a wide breadth of paper and poster presentations at the session all dealing with the applications of TIR data or thermal infrared sensor characteristics for Earth science research. Overall, the session was focused on several general themes: soil moisture and evapotranspiration measurements, volcanology, water resource management and lake studies, surface energy flux measurements, and urban heat island analysis. A complete listing of the abstracts for papers and posters presented in the session can be found at www.agu.org/cgi-bin/sessions5?meeting=fm06&sec=H (Hydrology Section: Sessions H31G, H32D, and H33E).

There were three invited papers given during the session.

- **Richard Allen** [University of Idaho] *The Need for High-Resolution Thermal Imaging in Water Resource Management* who talked about the importance of TIR data for measuring factors related to evapotranspiration and water resource management and water budget modeling.
- **Todd Steissberg** [University of California, Davis] *High-Spatial Resolution Thermal Infrared Satellite Images for Lake Studies* who discussed how TIR satellite images can be used to study transport processes in lakes.
- **Gregory Vaughan** [JPL] *Spaceborne Thermal Infrared Measurements of Volcanic Thermal Features* who described how TIR measurements of high-temperature volcanic features improve our understanding of volcanic processes and our ability to identify renewed volcanic activity, forecast eruptions, and assess hazards.

A number of other oral presentations were also given during the session.

- **Wim Bastiaanssen** [SEBAL North America, Davis, CA] *Use of High Resolution Thermal Landsat Data to Estimate Evapotranspiration Within the Imperial Irrigation District in Southern California*.
- **Andrew French** [USDA-ARS Arid-Land Agricultural Research Center] *Monitoring Vegetation Cover Changes Over a Semi-Arid Rangeland with Multispectral ASTER Thermal Infrared Emissivities*.
- **Robert Gillies** [Utah State University] *The Urban Heat Island Effect – Implications of Leaf Phenology*.
- **James Irons** [GSFC] *Thermal Imaging and the Landsat Data Continuity Mission* who noted the absence of a TIR sensor on the Landsat Data Continuity Mission (LDCM) in its current configuration.
- **William Kustas** [USDA-ARS Hydrology and Remote Sensing Laboratory] *Problems in the Applications of Thermal-based Energy Balance Models with Significant Sub-pixel Variability*.
- **Christopher Neale** [Utah State University] *Soil Moisture Modeling Using Two Energy Balance Approaches with Thermal Infrared Satellite Inputs*.
- **Thomas Pagano** [JPL] *The Spaceborne Advanced Visible and Infrared Imager (SAVII) Next-Generation Land Imager Instrument Concept*.
- **Dale Quattrochi** [NASA Marshall Space Flight Center] *The Need for High Spatial Resolution Multispectral Thermal Remote Sensing Data in Urban Heat Island Research*.
- **Michael Ramsey** [University of Pittsburgh] *The Critical Need for Moderate to High Resolution*

Thermal Infrared Data for Volcanic Hazard Mitigation and Process Monitoring from the Micron to the Kilometer Scale.

- **Mitchell Roffer** [Roffer's Ocean Fishing Forecasting Service, Inc., West Melbourne, FL] *Use of Thermal Infrared Remote Sensing Data for Fisheries, Environmental Monitoring, Oil and Gas Exploration, and Ship Routing*.
- **Qihao Weng** [Indiana State University] *Spatial and Temporal Dynamics of Land Surface Temperatures and Urban Heat Islands in Metropolitan Indianapolis Using MODIS Data*.

The prevailing voice that transcended throughout the session was that TIR data are critical for obtaining measurements of a wide variety of ecological, biophysical, solid Earth, surface energy flux, and landscape characterization parameters that are of significant importance to Earth science research objectives. There was a resounding call for continuity in TIR data collection that at the present is in jeopardy, because there are no new NASA Earth observing remote sensing satellites planned that have TIR sensors to continue thermal IR data collection beyond those on Terra.

Land Surface Phenology, Seasonality, and the Water Cycle

Co-Conveners: *Geoffrey M Henebry, South Dakota State University; Mark A Friedl, Boston University; Michael A White, Utah State University*

Summary: This set of three special sessions focused on processes at the interface between ecology and hydrology at seasonal time scales. For example, the widespread increase in latent heat flux at the annual onset of rapid vegetation growth across the extratropics induces a strong quasi-periodic forcing on the global water cycle. The increase in evapotranspiration is heralded by snow melting, soil thawing, and increased streamflow. In contrast, phenology in desert ecosystems is driven by largely aperiodic precipitation events. Building on the successes of phenology sessions in 2004 and 2005, three special sessions were convened at the Fall 2006 AGU that brought together current research exploring interactive linkages between the seasonality of abiotic processes, the phenology of biotic processes, and aspects of the water cycle.

Combined, all three sessions included 43 papers (12 oral and 31 posters), four of which were invited. The first oral session focused primarily on linkages between vegetation phenology and various dimensions of ecosystem function:

- **Phil Townsend** [University of Wisconsin-Madison] presented results from a study that explored relationships between gypsy moth infestation and flooding in mid-Atlantic states forest disturbance using 250 m Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) data.
- **Dennis Baldocchi** [University of California, Berkeley] presented a synthesis of research activities related to how phenology modulates carbon dioxide (CO_2) and water (H_2O) exchange, and vegetation-atmosphere interactions. He presented several interesting results showing the relationship between length of the growing season, precipitation, snow cover, variability in leaf physiology, and photosynthetic capacity. He also showed that the impact of phenology is much stronger on CO_2 than on water, and that boundary layer growth depends on phenology. He concluded by describing a simple method to model phenology and CO_2 exchange over space using soil temperatures, and a discussion of new field methods relevant to studies of phenology.
- **Michael White** [Utah State University] discussed recent results from a study that integrated remote sensing, phenology, and stream chemistry. By using watersheds as a unit of study, he showed strong empirical relations between variation in stream chemistry and vegetation phenology from Advanced Very High Resolution Radiometer (AVHRR) data at watershed scales. The results strongly suggest that the ecosystem phenology can exert strong influence on water chemistry over large areas.
- **Scott MacKay** [University of Buffalo] presented results from a study in which a detailed biophysical model was used in combination with detailed field measurements to study spatial gradients in transpiration and stomatal conductance at a field site in Wisconsin. His results showed seasonal agreement in observed and modeled conductance, and a lag between full leaf out and the photosynthetic "machinery" of the canopy.
- **Bethany Bradley** [Princeton University] discussed how phenology can be used as an indicator of global change, emphasizing the importance of regional variability and distinguishing long-term versus short-term variability. To this end, she presented results from a study in the Great Basin in which phenological information was extracted from a smoothed time series of AVHRR data. Using these data, Bradley developed a regional classification and examined the phenology of specific classes. Her results suggest that mountain ecosystems are sensitive to changes in climate.
- **Anatoly Gitelson** [University of Nebraska-Lincoln] presented a paper that examined which biophysical measures should be used to characterize phenology. He specifically focused on crops, and examined relationships among Fraction-of-Pho-

tosynthetically Active Radiation absorbed (FPAR), chlorophyll content, gross primary production, photosynthetically active radiation, and light use efficiency.

In the second oral session, papers focused on abiotic controls on hydrology and phenology.

- **Tom Schmugge** [New Mexico State University] discussed research where he examined emissivity data from MODIS and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) over sites in Mali, West Africa. The analysis specifically examined dependence of emissivity on soil water content, and results were highly mixed with few strong patterns emerging.
- **Wolfgang Wagner** [Vienna University of Technology, Austria] presented a synthesis paper describing the use of active microwave sensors to study land surface processes over seasonal time scales. He identified two main challenges in this context: (1) mapping freeze thaw—which can be achieved using a *diurnal difference method* and provides an effective way to map start and end of thaw/refreeze season; and (2) soil moisture—which significantly complicates the active microwave signal. His work suggests that active microwave data can be used to monitor anomalies in land surface hydrology.
- **Cheney Shreve** [University of Virginia] described a study that examined phenology in the Tibetan Plateau, and compared observed patterns in key controls including elevation and snow. Using derived phenological metrics derived from remote sensing, Shreve concluded that spring and summer precipitation dominate vegetation phenology in the region.
- **Geoffrey Henebry** [South Dakota State University] discussed how the vegetation product from the Advanced Microwave Scanning Radiometer—Earth Observing System (AMSR-E) might be used to explore diurnal and seasonal variations in vegetation water content. The dynamic range of the AMSR-E product exceeded that of MODIS vegetation products in study areas in herbaceous landscapes in Northern Eurasia and North America. Validation of the very coarse spatial resolution data poses a significant challenge.
- **Christa Peters-Lidard** [NASA Goddard Space Flight Center] presented results from field studies examining land-atmosphere coupling, focusing on interactions among soil moisture, vegetation, and the planetary boundary layer. To do this she used modeled and observed relationships between humidity and potential temperature to understand the nature and magnitude of land-atmosphere coupling. Her results show that the nature of land-atmosphere coupling depends on surface properties (e.g., phenology); a key result was that such analyses require coupled models.
- **Michel Verstraete** [European Union Joint Research Centre] discussed a study focusing on the role of phenology in vegetation-climate interactions. To this end, he described a study to use remote sensing to identify the start and end of the growing season objectively. To do this, he used FPAR measurements from remote sensing to extract a suite of phenological metrics. His results compared favorably with agricultural productivity data sets from Europe.

The poster session included 31 papers. Abstracts for these papers can be found at: *www.agu.org/meetings/fm06/fm06-sessions/fm06_B31A.html.*

Arctic System Science Press Release

MODERATOR: Larry Hinzman, Professor and Deputy Director of the International Arctic Research Center, University of Alaska, Fairbanks

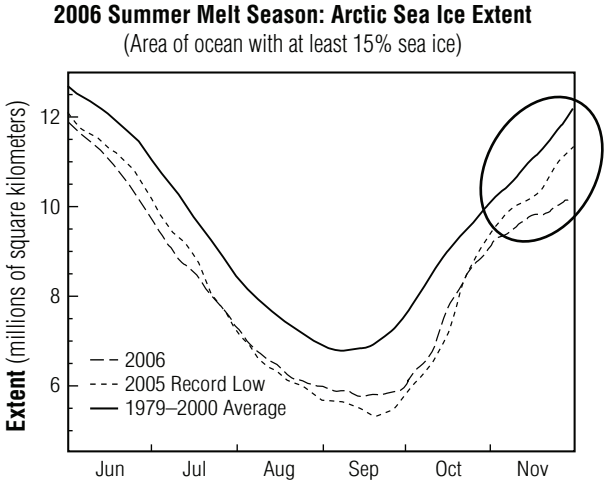
PRESENTERS:

Charles J. Vörösmarty, Research Professor, University of New Hampshire, *Large-scale freshening of the high northern latitudes and broader policy implications.*

Mark Serreze, Senior Research Scientist, National Snow and Ice Data Center, *Arctic climate variability and change, numerical weather prediction in high latitudes, and arctic atmosphere-ocean-ice interaction.*

James E. Overland, NOAA Pacific Marine Environmental Laboratory—*State of the Arctic—report and indicators show the importance of natural variability.*

The Arctic is an integral component of the larger Earth system and is itself a complex system. The Arctic's cryospheric, biological, climatological, hydrological, atmospheric, oceanographic, and terrestrial regimes are fully coupled and cannot be completely understood individually. No single piece of the system is independent. To fully understand even a portion of the system requires coordinated synthesis studies of the individual processes, their linkages, and their contributions to variability in the Arctic water, energy, and biogeochemical cycles. Because the Arctic is a vast and sparsely populated area, where integrated system studies are relatively new, there is much we do not know. Developing a sound predictive capability of climatic change and system level responses, despite sparse data and the region's severe climate, is challenging. The complexity and sensitivity of the arctic terrestrial and marine system responses to change yield broad, yet consistent evidence of rapidly changing physical, biological and social systems. The



Ice is no longer recovering well in autumn. At the end of November, 2006, ice extent was about 2 million km² below average (area larger than Alaska), beating out even 2005. **Credit:** National Snow and Ice Data Center.

only viable approach to understanding the complicated linkages within the arctic biological, physical, and social systems is through collaboration across disciplines with integration and synthesis across the national and international Arctic research community.

Scientists representing the largest group of Arctic research in the U.S. presented information on recent and significant findings with regard to a broad array of geophysical and biological indicators of Arctic system change.

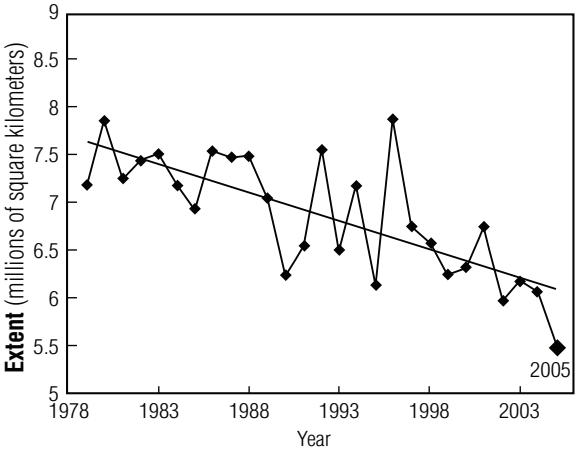
Recent studies indicate that within the next 50 years, the Arctic Ocean may be ice-free in summer, while corresponding changes on land include melting permafrost and the expansion of trees and shrubs across the tundra. Changes in the Arctic are linked to one another, with potentially magnified cumulative effects. As warming continues, impacts on industrial development and Arctic residents will become more apparent and widespread. Among the key changes:

- **Arctic air temperatures are increasing:** Average air temperatures have risen strongly in recent decades and are now higher than they have been in at least six centuries. In 2005, large portions of the Arctic were 2-4°C (4-7°F) warmer than the average temperatures over the previous 26 years.
- **Sea ice is diminishing:** Arctic sea ice has progressively diminished over the past 30 years; in September 2005 scientists observed the least amount of sea ice ever recorded by satellites. In 2006, refreezing of sea ice in November lags recovery of previous years.
- **Permafrost is warming and thawing:** Over the last 25 years, permafrost has warmed dramatically and is thawing in places throughout the Arctic, putting ecosystems and human infrastructure at risk.
- **Woody shrubs are expanding across the tundra:** Shrubs are becoming larger and more abundant throughout the Arctic tundra, potentially altering ecosystem function and interfering with oil exploration and caribou migration.
- **The Greenland Ice Sheet is melting:** If global temperatures continue to increase as projected by models, continued melting of the Greenland Ice Sheet would contribute to a rise in global sea level of 13–19 feet or more over the next several centuries.
- **Arctic rivers are discharging more freshwater into the oceans:** Freshwater flowing into the Arctic Ocean through rivers is increasing and may alter global ocean circulation patterns, which would have significant impacts on global climate, ocean ecosystems, and global food production. A general hemispheric-scale redistribution of moisture is moving freshwater northward.

While many of these changes have already been documented, it is their recent persistence, interactions, and coherence that today underpins an emerging science that considers the Arctic system as a whole.

- The Arctic system for the past five years is markedly different from the 20th Century.
- Despite the fact the Arctic is a moving target, the scientific community is meeting the challenge of understanding how the system functions as a whole.
- New advances in Arctic system science show that changes in sea ice, temperature, and freshwater cycles, are coordinated, link the Arctic to the global system and have potential tipping points.

These changes are already affecting policy debate. While there is much debate regarding how to best manage the negative impacts of climate change, we also see an emerging dialogue on how climate change could stimu-



The Arctic's floating sea ice cover has declined sharply in the past 25 years, with extreme losses in recent years. The Arctic has warmed strongly. In 2005, when September sea ice extent reached a new record low, Arctic air temperatures were 2-4° C (4-7° F) above normal. **Credit:** National Snow and Ice Data Center.

late economic enterprise from the private sector, such as the opening of trade routes across the Arctic Ocean. Increased extraction and use of resources is likely to accompany these biogeochemical changes, ushering in economic opportunity and environmental and social changes in the Arctic and beyond. New research is taking aim at understanding the linkages—including those associated with human systems—within the Arctic system as a whole, and of the Arctic's connections with the broader Earth system.

Summary: Variations of the total solar irradiance (TSI) have been measured since 1978 and modeled for preceding millenia using various proxies. Phenomemological analyses of measured and modeled TSI and northern hemisphere temperature records have produced new estimates of climate sensitivity to solar variations on different time scales that significantly exceed past predictions of global circulation models. The relative impact of solar and anthropogenic forcing of climate change can now be more accurately addressed. ■

Total Solar Irradiance Variations and Their Impact on Climate

***Co-convenors**; Richard Willson [Columbia University]; Nicola Scafetta [Duke University]*

The papers presented were designed to address solar total irradiance variability and its climate change significance and the titles are listed in the Table below. Full presentations may be viewed at *www.acrim.com.*

Topic	**Presenter(s)** [Affiliation]
Secular Variations of Solar Activity and Irradiance' on Millenial Time Scales	**Sami Solanki** [Max Planck Institute for Solar System Research]
A Critical Review of the Time Series of Total Solar Irradiance Satellite Observations	**Dick Willson** [Columbia University]
Surface Temperature Reconstructions for the Last 1000 Years	**Gerald North** [Texas A&M University]
A Phenomenological Reconstruction of the Solar Signature in the Northern Hemisphere Surface Temperature Records Since 1600	**Nicola Scafetta** [Duke University]
A Comparison of Sunspot Photometric Indices From Ground-Based Data and MDI/SOHO	**Gary Chapman** [California State University at Northridge]
Tropospheric Adjustment: the Responses of Temperature and Precipitation to a Change in Solar Forcing	**F. Hugo Lambert** [Oxford University, U.K.]

Workshops on Ocean Salinity and Aquarius/SAC-D Mission Held

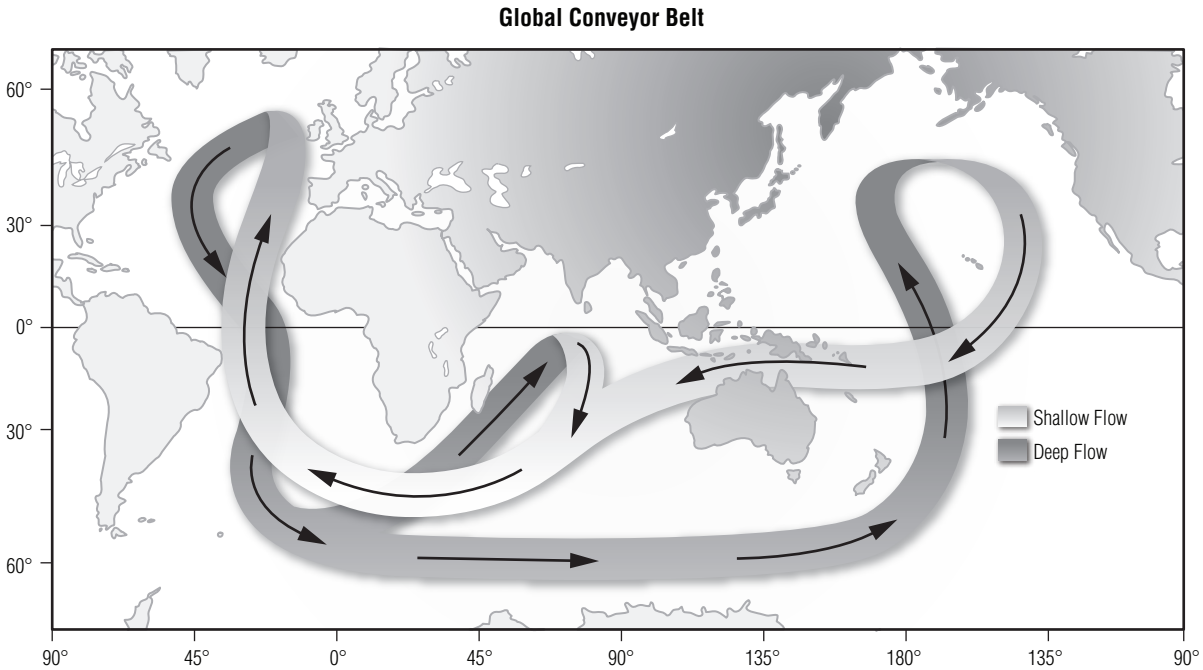
Gary Lagerloef, Aquarius Principal Investigator, Earth and Space Research, lager@esr.org

Changes in Ocean Salinity Can Impact Global Climate

Changes in the global water cycle can cause changes in the salinity of the oceans. Simply put, the more fresh water that enters the oceans, the more diluted the salt concentration of the water at the surface and possibly beyond. The salinity of ocean water impacts ocean circulation and the mixing of ocean water, and these changes can have impacts on climate. Research shows that over the past 50 years, Arctic and sub-Arctic oceans have become less salty while subtropical oceans of the North Atlantic and North Pacific have become more salty. There is also evidence to suggest that this change is spreading beyond the ocean surface and starting to impact subsurface ocean layers, which may begin to affect the ocean's *thermohaline circulation*—a circulation driven by differences in density of water at different levels of the ocean, sometimes called the *global conveyor belt*—see illustration below. Major changes in this global conveyor belt have changed global climate in the past and could have profound impacts on Earth's future climate.

The oceans contain 97% of the Earth's free water, are responsible for 86% of global evaporation, and 78% of global precipitation. There is increasing evidence that suggests that terrestrial flood and drought cycles are linked to variations in the oceanic water cycle. Any change in the water cycle impacts the ocean's ability to both store and transport heat, which impacts global climate. Scientists don't fully understand how all of these different processes are connected, but they expect to get some new insights in the next few years as new satellite sensors will be launched that will detect sea surface salinity (SSS) trends of the marine hydrological cycle on seasonal to interannual timescales from space. These sensors will give scientists powerful new tools to help them understand why this change in salinity is happening and how it is affecting ocean circulation, and ultimately, the Earth's climate.

In light of recent scientific findings that suggest ocean salinity is changing and in light of the new tools that will soon be available for measuring salinity *in situ* and from space, the ocean community decided to organize two workshops to discuss key issues and future plans. More than 80 research scientists and agency managers participated in the combined U.S. Climate Variability and Predictability (CLIVAR) and Aquarius/Satélite



Shown here is an illustration of the *thermohaline circulation* or *global conveyor belt*. The thermohaline circulation (THC) is a term for the global density-driven circulation of the oceans. Derivation is from *thermo-* for heat and *-haline* for salt, which together determine the density of sea water. Wind driven surface currents (such as the Gulf Stream) head polewards from the equatorial Atlantic Ocean, cooling all the while and eventually sinking at high latitudes (forming North Atlantic Deep Water). This dense water then flows into the ocean basins. While the bulk of it upwells in the Southern Ocean, the oldest waters (with a transit time of around 1600 years) upwell in the North Pacific. Extensive mixing therefore takes place between the ocean basins, reducing differences between them and making the Earth's ocean a global system. On their journey, the water masses transport both energy (in the form of heat) and matter (solids, dissolved substances and gases) around the globe. As such, the state of the circulation has a large impact on the climate of the Earth.

Aplicaciones Cientîficas (SAC-D) Salinity Satellite Mission Workshops at Woods Hole Oceanographic Institution (WHOL) May 8-12, 2006. Following is the report from the two workshops; a more detailed report appears in the October 24, 2006, issue of the American Geophysical Union's (AGU) *EOS* newsletter.

U.S. Climate Variability and Predictability (CLIVAR)

CLIVAR was established in 2005 with the following charter:

- Describe the role of ocean salinity in the global water cycle, global ocean circulation, and climate variability (including trends).
- Identify the requirements and challenges for analyzing, observing, and monitoring salinity, as well as simulate processes critical for determining the ocean's role in transport and storage of salinity.
- Provide guidance to NASA (and the international community) on observational and scientific activities that should be considered in advance of and during the Aquarius/SAC-D satellite mission to improve our measurement, analysis, and utilization of salinity information for the purposes stated above.
- Report to the U.S. CLIVAR Phenomena, Observation, and Synthesis panel on the above objectives.

The CLIVAR Salinity Workshop in May was a follow-on to a special session held at the AGU-sponsored Ocean Sciences Meeting in Honolulu, HI, in February 2006 called *The role of ocean salinity in climate*. The May workshop was devoted to five special sessions focusing on:

1. *Surface water fluxes and the latest research data sets and global analyses.* The session included overviews of evaporation, precipitation, and net surface flux fields.
2. *Salinity structure, trends, and variability.* The session included discussions of upper ocean thermohaline structure and evolution, updates on large-scale decadal ocean salinity trends, and issues in various regions like the North Atlantic, North Pacific, tropical oceans, etc.
3. *Salinity and climate.* This session covered salinity and El Niño predictability, and paleosalinity issues.
4. *Observations and monitoring opportunities.* The focus here was on salinity trends, thermosalinographs, and new technology developments for *in situ* sensors.
5. *Future prospects.* This session examined the practicalities and benefits of measuring ocean surface salinity from space. It provided an overview of the Aquarius/SAC-D satellite mission currently scheduled to launch in 2009, and considered the application of improved salinity measurements to constrain oceanic fluxes in ocean models and data assimilation.

Each session included a series of invited talks but also included dedicated time for lengthy discussion of key issues and future plans. There was also an open forum for poster presentations.

After the five sessions, there was a general discussion about the design of a regional experiment to quantify the net air-sea freshwater fluxes. In this experiment, seasonal changes in SSS would be monitored by satellite and *in situ* measurements, and compared with changes expected based on precipitation/evaporation fields from satellite or reanalysis sources. Participants agreed that the experiment needed to be done in an ocean region with a large seasonal water cycle budget and SSS signals, and where oceanic advection plays a minor role. The subtropical region of the North Atlantic and the Bay of Bengal were considered.

The CLIVAR Salinity Working Group is compiling a *white paper* which includes a thorough literature review, topical chapters according to the workshop themes, and recommendations for CLIVAR program initiatives focusing on the marine branch of the water cycle. It is expected to be complete by mid-2007.

Aquarius/SAC-D Science Workshop

This workshop followed the CLIVAR Salinity Workshop. The goal was to provide information to the science community about Aquarius/SAC-D salinity measurements and also included an overview of the European Soil Moisture and Ocean Salinity (SMOS) Mission.

Aquarius/SAC-D is an Earth System Science Pathfinder (ESSP) mission with an international partnership between the U.S. and Argentina, with NASA providing the primary salinity-measuring instrument, data system, and launch, and the Comisión Nacional de Actividades Espaciales (CONAE)—the Argentine Space Agency—providing the satellite system, mission operations, and several Argentine and third-party science instruments. Aquarius will provide global surface salinity measurements with a monthly error of 0.2 PSS-78 or less at 150 km resolution scales which will be valid for the open ocean (more than 450 km from coastal and ice boundaries).

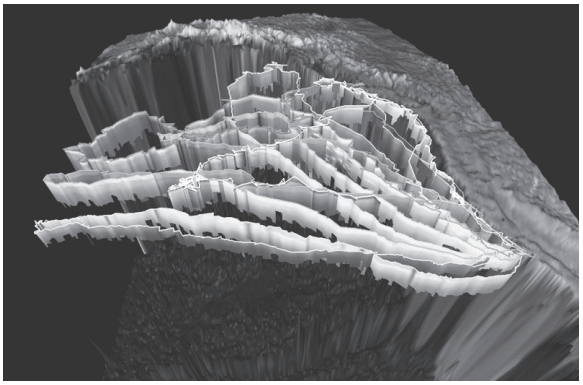
Participants learned about all aspects of the mission including mission design, retrieval algorithms, data products, validation plans, and education and public outreach. They then heard additional science presenta-

tions that paralleled the general themes established in the CLIVAR workshop (see above) but with consideration for ways the satellite data would be used.

The following recommendations were made:

1. Reassess the small retrieval model function errors and continue to develop improvements.
2. Intensify the research, measurements, and modeling of the surface layer salinity profile in the upper five meters to resolve the validation errors from using Argo data (most Argo floats do not sample between five meters and the surface) and to better understand the surface layer physics and mixing schemes for numerical models.
3. Establish closer collaboration with Argo regarding requirements, technical developments, and funding to better serve these needs.
4. Provide a sea surface density (SSD) data set based on the new satellite SSS and ancillary sea surface temperature (SST) data in both long-track swath resolution and gridded products.
5. Restate science measurement objectives (3-year+ satellite mission): (1) map the global mean SSS and SSD fields with standard deviations; (2) resolve the SSS and SSD annual cycle, with error bars; and (3) measure interannual (climatic) variations.
6. Develop stronger programmatic linkage with CLIVAR, especially field program initiatives that serve both the broader science objectives and enhanced satellite data validation efforts.

For more information on Aquarius, the web site is located at *aquarius.gsfc.nasa.gov*. ■



Satellites and Sea Lions: Working Together to Improve Ocean Models
Sea lions, seals, sharks, tuna, and other top ocean predators share some of their experiences with human researchers, thanks to electronic tags. Besides tracking the animals, these sensors also collect oceanographic data, such as temperature and salinity. Scientists are beginning to incorporate this rich store of information into ocean models providing new insights into the inner workings of the ocean and the lives of its creatures. (*top*) A male sea lion shares his intimate knowledge of the ocean with researchers via an electronic tag. **Image Credit:** Mike Weise. (*lower left*) The field team attaches a tag to the fur of a sedated male elephant seal. Special permits are required for this work to ensure the animal's protection. **Image Credit:** Daniel Costa. (*lower right*) Temperature profiles generated by seven elephant seals traveling across the North Pacific. **Image Credit:** Daniel Costa. For color images and full story visit: *www.nasa.gov/vision/earth/lookingatearth/sealion-20070206.html.*

New Aura-OMI Level-2 Atmospheric SO_2 Product Released

In pre-industrial times, volcanoes were the primary sources of sulfur dioxide (SO_2), but anthropogenic fossil fuel combustion is now a far larger source. The sulfate aerosols produced from volcanic eruptions and fossil fuels are significant factors in climate change. A 25-year record of volcanic eruption SO_2 input was produced from Total Ozone Mapping Spectrometer (TOMS) data. Ozone Monitoring Instrument (OMI) data are now extending this record and enhancing it through coverage of passive volcanic emissions, smelter plumes, and fossil fuel air pollution.

The Aura-OMI Level-2 Sulfur Dioxide Product *OMSO2* is now publicly available—*disc.gsfc.nasa.gov/Aura/OMI/omso2.shtml*—from NASA's GSFC Earth Sciences (GES) Data and Information Services Center (DISC). Due to the combination of a smaller footprint and measurements at wavelengths that are highly sensitive to SO_2 absorption, the minimum SO_2 mass detectable by OMI is better (two orders of magnitude lower) than the detection threshold of earlier TOMS SO_2 measurements.

The algorithm team responsible for the SO_2 data product consists of **Nickolay Krotkov** (algorithm lead), **Arlin J. Krueger**, **Kai Yang** and **Simon Carn** from the University of Maryland, Baltimore County.

In the *OMSO2* product, three values of SO_2 Vertical Column are provided corresponding to three SO_2 source regimes: SO_2 in the Planetary Boundary Layer (PBL, below 2 km) from anthropogenic sources, SO_2 distributed between 5 and 10 km emitted by passive volcanic degassing in the free troposphere, and SO_2 distributed between 15 and 20 km representing injection from explosive volcanic eruptions. The user is advised to select the SO_2 column value most consistent with the expected SO_2 vertical distribution for their specific application.

OMI data are processed at the OMI Science Investigator-led Processing System (OSIPS) at NASA/GSFC. The standard OMI derived products are made broadly available from the GES DISC Atmospheric Composition web site: *acdisc.gsfc.nasa.gov/*.

OMI Ozone, NO_2, Cloud and Aerosol products have been released earlier. The rest of the OMI products will be released in the near future. For the full set of Aura products available from the GES DISC, please see: *disc.sci.gsfc.nasa.gov/Aura/data_products.shtml.*

New Aura-OMI Level-2 Aerosol Product Released

The Aura-OMI Level-2 Aerosol Product *OMAERUV* is now publicly available—*disc.gsfc.nasa.gov/Aura/OMI/omaeruv.shtml*—from NASA's GSFC Earth Sciences (GES) Data and Information Services Center (DISC). The *OMAERUV* product consists of Aerosol Extinction Optical Depths (AOD) and Aerosol Absorption Optical Depths (AAOD) at 354, 388 and 500 nm, and UV Aerosol Index (AI) calculated using measurements at 354 and 388 nm. The PI of the *OMAERUV* Aerosol Data Product is **Omar Torres** from the University of Maryland, Baltimore County.

OMI aerosol products also include another UV AI (based on the 331 and 360 nm measurements), as a by-product in the retrieval of the column ozone amount by the *OMTO3* algorithm. The *OMTO3* UV AI is also publicly available from the GES DISC—*disc.gsfc.nasa.gov/Aura/OMI/* or *acdisc.sci.gsfc.nasa.gov/Giovanni/omi/*. The definition of the *OMTO3* UV AI is identical to the one used in the *version-8* TOMS AI. Users interested in the long-term continuity of the UV AI data are, therefore, advised to use the *OMTO3* AI product.

OMI data are processed at the OMI Science Investigator-led Processing System (OSIPS) at NASA/GSFC, the OMI Dutch Processing System (ODAPS) at Netherlands Royal Meteorological Institute (KNMI), the Netherlands, and at Finnish Meteorological Institute (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 web site, *acdisc.gsfc.nasa.gov/*.

Another aerosol product *OMAERO,* based on a spectral fitting algorithm, is currently under development at the KNMI. OMI Ozone, NO_2 and Cloud products have been released earlier. The rest of the OMI products will be released in the near future. For the full set of Aura products available from the GES DISC, please see: *disc.sci.gsfc.nasa.gov/Aura/data_products.shtml.*

TES Science Team Meeting Overview

Annmarie Eldering, NASA Jet Propulsion Laboratory, Annmarie.Eldering@jpl.nasa.gov

The 30th Tropospheric Emission Spectrometer (TES) Science Team meeting was held on November 13-14, 2006, at the University of Phoenix in Pasadena, California. There were 50 attendees. The first day focused on project status and algorithms, and had one science session on the water cycle. The second day was science focused, with sessions on Continental and Global-Scale Pollution, Regional Air Quality, POLARCAT/ARCTAS, Data Assimilation and Modeling, and on new measurement ideas.

Project Status, Algorithms, and Data

The primary focus of the first day was to update the team on the status of the project and discuss algorithms. The first session of the second day was an overview of TES data, format, accessibility, and support tools and information.

Reinhard Beer [Jet Propulsion Laboratory (JPL)—*TES PI*] opened the meeting. Beer welcomed everyone to the meeting and turned the floor over to **Mark Schoeberl** [Goddard Space Flight Center (GSFC)—*Aura Project Scientist*]. Schoeberl discussed the upcoming re-proposal of core activities and the need for proposals that included use of the data by the external community and new science activities. Schoeberl encouraged the TES team to continue their contributions to the *Aura Top 10* Science Results. For additional information on Aura science results, see aura.gsfc.nasa.gov/science/sciencegallery.html.

Rob Toaz, Jr [JPL—*TES Project Manager*] addressed the meeting, providing an overview of project highlights and instrument operations. TES performed special observations throughout the Intercontinental Chemical Transport Experiment, Phase B (INTEX-B) field campaign this spring, as well as in support of the Texas Air Quality Field Study (AQS). On July 20, 2006, *v002* reprocessing was completed for all TES observations. Toaz pointed out the resources available for users at the Langley Atmospheric Science Data Center (ASDC)—*eosweb.larc.nasa.gov/PRODOCS/tes/table_tes.html*—including the *TES User's Guide* and the validation report. Toaz showed highlights from a short movie about TES that was produced for the JPL open house, and he also reviewed a list of the 19 papers published since launch.

Doug Shepard [JPL—*Ground Data System Manager*] provided an overview of the current data processing status and upcoming plans. The Science Investigator-led Processing System (SIPS) is current with the TES data stream, and will continue until late December 2006 when the Global Modeling and Assimilation Office's (GMAO) Goddard Earth Observing System Model, *Version 5* (GEOS-5) assimilation system's forward production stream becomes available. At that time, TES will begin processing with a new data release to produce *v003* products. The new release has significant updates to the Level 2 (L2) retrieval algorithm, including improved spectroscopy for Carbon Dioxide (CO_2) and improved temperature retrievals achieved by including additional spectral regions in the water/temperature retrieval steps. Reprocessing with *v003* is expected to take about 9 months. New Level 3 (L3) browse and data products are to be delivered in April 2007.

Greg Osterman [JPL] provided an update on the data product validation. The year 2006 was a busy one for validation field campaigns—e.g, INTEX-B,Texas AQS, Costa Rica Aura Validation Experiment (CR-AVE), Tico sonde, Atmospheric Radiation Measurement (ARM) site ozonesonde launches, Megacity Initiative: Local and Global Research Observations (MILAGRO), Intex Ozonesonde Network Study (IONS 2006), Sodankylä Total Ozone Intercomparison (SAUNA), Water Vapor Validation Experiment Satellite/Sondes (WAVES), and Measurements of Humidity in the Atmosphere Validation Experiment (MOHAVE). These data are being used extensively, and as of September 2006, TES nadir ozone (O_3) and carbon monoxide (CO) are considered validated (Stage 1), nadir water vapor (H_2O), atmospheric and surface temperature, and deuterium (HDO) are provisionally validated, and nadir methane (CH_4) and all limb products are considered *beta*. The validation work will focus on bringing the *beta*-validated products to provisional validation status in 2007. Osterman discussed more details of each data product. This information can be found in the TES validation report at the Langley ASDC.

Ming Luo [JPL] described the L3 data products that are currently in development. There will be gridded data products, produced for daily and monthly data sets from TES Global Survey measurements. They are reported at the Upper Atmosphere Research Satellite (UARS) pressure levels plus the surface and 825 hectoPascals (hPa). Browse products and images will be viewable on the data ordering page at the Langley Distributed Archive Center (DAAC). These will include *dot plots* and interpolated L3 maps.

The next set of presentations discussed the status of the TES algorithms.

- **Susan Kulawik** [JPL] provided an update on the TES limb data products and future direction. The upcoming data version, *v003*, will include limb retrievals that extend into the troposphere in clear scenes. Kulawik explained the retrieval steps of pointing angle, cloud detection, water, and tem-

perature, and then nitric acid (HNO_3) or O_3. Currently, temperature retrievals for limb scans 5 and 6 agree well with National Centers for Environmental Prediction (NCEP) sondes, while the temperature retrievals for scan 4—used for HNO_3 retrievals—do not agree well with NCEP sondes. Despite this temperature disagreement, the TES HNO_3 retrievals agree with the retrievals from the Microwave Limb Sounder (MLS) between 10 and 100 hPa.

- **Clive Rodgers** [University of Oxford—*TES Co-Investigator (Co-I)*] discussed his singular value decomposition analysis of nadir radiance spectra. A constituent may appear in one singular vector, indicating that it is uncorrelated with other sources of variability. Rodgers focused on analysis of data from biomass burning areas, selected by Ming Luo. The search for signals from formic acid (HCOOH), ethylene (C_2H_4), and carbonyl sulfide (OCS) has not yet proven fruitful.
- **Mark Shephard** [Atmospheric and Environmental Research Inc. (AER)] showed temperature and water comparisons using radiosonde data and radiance closure calculations. Shephard discussed the *v002* TES biases in detail—see the validation report for more details at *eosweb.larc.nasa.gov/PRODOCS/tes/validation/*. The radiance closure calculations demonstrate that there are radiance biases in the CO_2 region (60-800 cm^{-1}) consistent with TES temperature retrievals being 1K too cold in the upper troposphere. This bias is significantly reduced in the *v003* retrievals.
- **Jennifer Logan** [Harvard—*TES Co-I*] discussed Global Modeling Initiative (GMI) Combo simulations and comparisons with TES for O_3. The GMI Combo model includes stratospheric and tropospheric chemistry. Some differences are apparent in the tropical Atlantic, especially in July/August, from Brazil to Africa in October and November, and over Central Africa in December. Analysis will continue and extend to CO.
- **Susan Kulawik** discussed CH_4 retrievals. She showed preliminary retrievals for *v003* that have much more believable latitudinal gradients than *v002*. CH_4 validation will be an important activity for *v003*. Kulawik also discussed an improved simulation test set that is used to test proposed algorithm updates. The improved simulation dataset includes land surfaces and more realistic temperature profiles.
- **Susan Kulawik** and **John Worden** [JPL] previewed *v003*, describing the increased degrees of freedom for temperature and O_3, and the fact that *v003* temperature profiles have very little bias compared to NCEP sondes, while TES was 1K cooler than the sondes in much of the troposphere in *v002*.
- **Tony Clough** [AER—*TES Co-I*] contributed a talk on spectroscopy and the TES forward model. He showed that the inclusion of line coupling in the forward model for CO_2 improves the spectral residuals as well as the temperature profile comparisons against radiosondes. Spectral residual shows that there are no outstanding issues with the water vapor continuum.

Annmarie Eldering [JPL—*Acting Deputy PI for TES*] began the second day of the meeting with an overview of TES data, format, accessibility, and support tools and information. Eldering reviewed TES observation modes and aspects of the data products like averaging kernels and errors, and highlighted important links at the Langley ASDC for data ordering, data user's guide, product calendar, and IDL code that reads the data product files.

Science Discussions

A series of discussions on science-related topics took place during the meeting. The first discussion occurred in the late afternoon of the first day, while the others took up the majority of the second day of the meeting. Highlights of each discussion are presented below. The leader(s), and their affiliation, of each session are listed after the session title.

The Water Cycle—**John Worden** [JPL]

- **David Noone** [University of Colorado] showed results and ongoing studies that utilize the HDO measurements from TES. This work will appear in *Nature* in early 2007. They found that in the tropics and in regions of tropical rain clouds, rainfall evaporation significantly re-hydrates the lower troposphere, with typically 20% and up to 50% of rain evaporating before it reaches the ground. The atmosphere retains this water, which can be used to make more clouds. The strength and location of this evaporation gives scientists new insights into how efficiently Earth's atmosphere moves energy from its surface upwards. This is important, since the main role of the atmosphere in Earth's climate system is to take energy from the sun and dispose of it back into space.
- **Frank Li** [JPL] and **Duane Waliser** [JPL] showed how they are using new remote sensing datasets to study clouds in Global Climate Models (GCMs). The particular focus of their work is upper-tropospheric cloud ice content, comparing MLS measurements to a number of GCM simulations. They show that predictions of ice water path between different models differ by more than 100%. After analysis with MLS, the European Center for Medium-range Weather Forecasting (ECMWF) revised the moist physics package in their model, and there is improved agreement with MLS. They are starting to include CloudSat data in their analysis.

Regional and Global Scale Pollution—**Kevin Bowman** [JPL] and **Helen Worden** [JPL]

The focus of the session was to discuss how we can quantify import and export budgets and trends, differentiate between the impact of natural and anthropogenic sources, and characterize pollution pathways and transport processes.

- **Worden** gave a presentation on tropical Atlantic ozone, showing model sensitivity of the Global 3-D Chemistry Model driven by the Goddard Earth Observing System (GEOS-CHEM)—see *www-as.harvard.edu/chemistry/trop/geos/*—to biomass burning for CO, NO_2, and O_3, and then plots of monthly averages of TES O_3 and CO for a number of tropical regions. This analysis suggests that there may be unmodeled sources of oxides of nitrogen (NO_x), and this topic will be the focus of future investigations.
- **Line Jourdain** [JPL/Caltech] followed with a presentation on TES observations of the North American pollution outflow in summer 2006. Jourdain showed examples of elevated CO over the North Atlantic and ozone over the Southeastern U.S.
- **Greg Osterman** [JPL] introduced the TES special observations made over the U.S., and described enhanced CO concentrations observed over the Southeastern U.S.
- **Susan Kulawik** [JPL] discussed ozone events over the Pacific Ocean. Kulawik's analysis shows the seasonal and spatial patterns of ozone in the lower, middle, and upper troposphere as observed by TES, including some high ozone between 20-40° N in the lower troposphere.
- **Annmarie Eldering** described analysis that is beginning to use TES observations and a particle dispersion model called FLEXPART to study the North American ozone budget. This focuses on August 2006, and complements the intensive ozonesonde campaign that was conducted.
- **Daniel Jacob** [Harvard—*TES Co-I*] presented analysis on the impact of Asian CO and O_3 on the U.S., showing that the impacts in the middle troposphere were clear, but impacts on surface concentrations are more muted.
- **Merritt Deeter** [National Center for Atmospheric Research (NCAR)] described *version 4* products from Terra's Measurements of Pollution in the Troposphere (MOPITT) instrument, and he highlighted improved *a priori*, additions to the product (e.g., averaging kernels, *a priori*, diagnostics), and an increase in the number of retrieval levels.

Regional Air Quality—**Greg Osterman** [JPL] and **Kevin Bowman** [JPL].

- **Brad Pierce** [NASA Langley] discussed work to synthesize near-real time satellite, airborne, surface, and assimilated data sets to use in air quality assessment on a regional scale during the 2006 NOAA Texas AQS. This case study illustrates the influence of remote emissions from the Southeast U.S. and Pacific Northwest on air quality in Houston, TX, and demonstrates the importance of integrating satellite, aircraft, and surface measurements in conjunction with advanced modeling techniques for characterizing the impact of emissions from remote sources on local air quality.
- **Jim Szykman** [Environmental Protection Agency (EPA)] provided an overview of the U.S. contribution to the Global Earth Observation System of Systems (GEOSS). Of particular interest to the TES group was his description of the joint NASA-NOAA-EPA initiative called *Infusing satellite Data into Environmental Applications (IDEA)*. The current demonstration predicts aerosol optical depth over the continental U.S. Additionally, EPA researchers are using CO data from MOPITT to assess synoptic scale CO features in the Models-3 Community Multiscale Air Quality modeling system (CMAQ).
- **Amir Hakami** [Caltech] discussed a satellite-based inversion of NO_x emissions using the adjoint of CMAQ. This study focused on the Southeast U.S. and uses Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCHIAMACHY) tropospheric NO_2 columns.

POLARCAT/ARCTAS Field Campaign—**John Worden** [JPL]

- **Worden** showed his analysis of TES polar measurements of CO and O_3 that show the spring and early summer maximum, respectively. Worden also showed O_3 and CO measurements influenced by boreal fires, and how TES special observations were useful during the INTEX campaign.
- **Daniel Jacob** then discussed ongoing planning for the Polar Study using Aircraft, Remote Sensing, Surface Measurement, and Models of Climate Chemisty, Aerosols, and Transport/ Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (POLARCAT/ARCTAS) field campaign in 2008—see *www.espo.nasa.gov/arctas*. Discussion ensued about the roles of stratospheric/tropospheric exchange, additional datasets such as MLS, and how we can use some advanced flight planning techniques.

Data Assimilation and Modeling—**Kevin Bowman** [JPL]

- **Dylan Jones** [University of Toronto] showed ongoing work that includes chemical data assimilation of TES observations into the GEOS-CHEM model using sequential sub-optimal Kalman filtering. This work shows that biomass burning impact on CO and O_3 in the southern hemisphere is underesti-

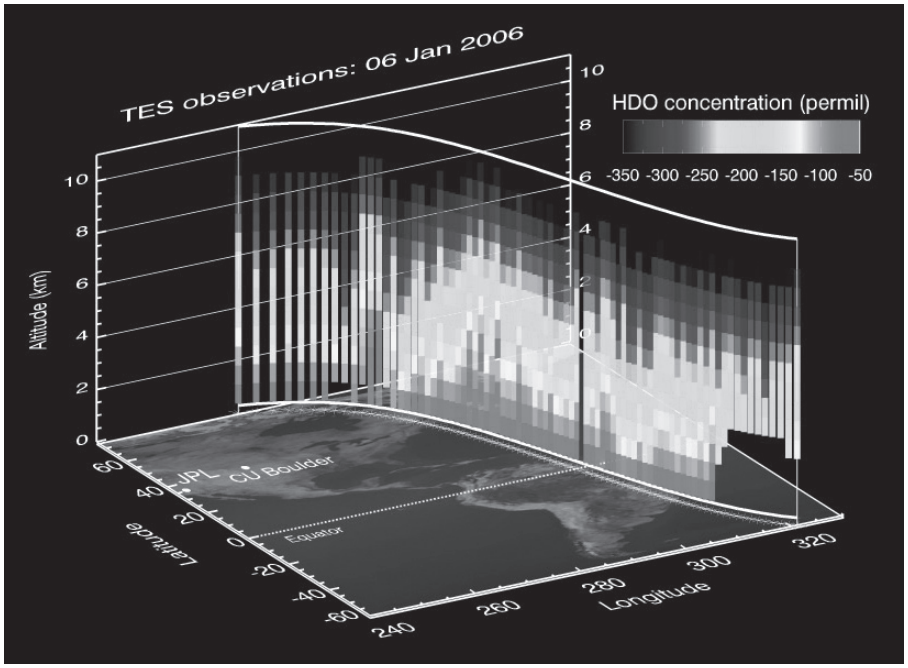
mated. Jones is also performing data assimilation with the AM-2 model.

- **Adrian Sandu** [Virginia Tech] discussed his assimilation work that uses a 4-D variational analysis system called VAR, and ensemble Kalman filter techniques. Sandu showed an example of assimilation for ozone prediction over the Eastern U.S. and highlighted the need for measurements above the surface and new approaches to provide boundary conditions to regional models.
- **Bryan Duncan** [GSFC] and **Anne Douglass** [GSFC] presented new results from the Global Modeling Initiative (GMI) COMBO model that includes dynamics and chemistry in the troposphere, stratosphere, and upper troposphere/lower stratosphere. Duncan and Douglass showed a few examples of comparisons of GMI COMBO with MLS, AIRS, and OMI.

New Science Directions and Ideas About Future Measurement Requirements and Capabilities—**John Worden** [JPL] and **Annmarie Eldering** [JPL].

- **Worden** discussed simulations that have been performed to characterize retrievals from combined TES and Ozone Monitoring Instrument (OMI) radiances. This analysis shows that combined wavelengths can result in an improvement of a factor of 2 in boundary layer ozone degrees of freedom.
- **Stan Sander** [JPL—*TES Co-I*] presented material on the advantages of high spectral resolution measurements of NO_2. Sander and his group are making direct solar absorption measurements at Table Mountain, CA and derive diurnal NO_2 columns. They are working on profile retrievals from this same data set.
- **Helen Worden** [JPL] shared recent analysis of the top-of-the-atmosphere (TOA) flux in the ozone band (985-1080 cm^{-1}) and its dependence on ozone amounts in the upper and lower troposphere, using TES radiance measurements and retrieved profiles. TES data show that upper tropospheric ozone is about twice as effective as a greenhouse gas than lower tropospheric ozone.

The concluding discussions focused on the new science discoveries that are ahead with the wealth of data from EOS Aura. TES data products are validated or in the process of being validated, and are useful for scientific analysis. At this meeting, presentations reported on studies of global and regional air pollution that incorporate not only TES data, but also data from OMI, MLS, SCHIAMACHY, ground-based measurements, and aircraft. There are a wide range of techniques being put to use—e.g., analysis of observations, assimilation, and incorporation into policy planning. The results of the current research and analysis provide valuable ideas about the future direction of atmospheric composition measurements. ■



NASA's newest detective in the mysteries of atmospheric water vapor is the Tropospheric Emission Spectrometer (TES) instrument on the Aura satellite. This view from TES depicts the distribution of "heavy" and "light" water vapor molecules over Earth's tropics. The lower portion of the vertical bars illustrate heavy water vapor (HDO), which indicates recent evaporation or plant "exhalation." The upper portion of the bars show lighter water vapor (H_2O) that has undergone significant condensation. The data was obtained October 7, 2006. For color image and more information please see: *www.nasa.gov/mission_pages/aura/media/tes-20070131.html.* **Credit:** NASA/JPL

2006 Was Earth's Fifth Warmest Year

Leslie McCarthy, Goddard Institute for Space Studies, Leslie.M.McCarthy@nasa.gov

Climatologists at the NASA Goddard Institute for Space Studies (GISS) in New York City have found that 2006 was the fifth warmest year in the past Century.

According to NASA scientists, the five warmest years since the late 1880s, are in descending order are: 2005, 1998, 2002, 2003, and 2006.

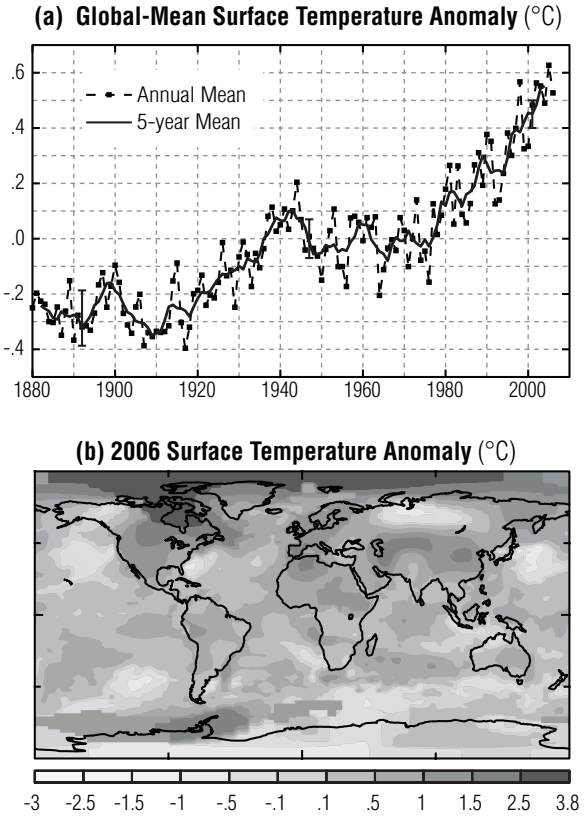
Other groups that study climate change also rank these years as among the warmest, though the exact rankings vary depending upon details of the analyses. Results differ especially in regions of sparse measurements, where scientists use alternative methods of estimating temperature change.

Goddard Institute researchers used temperature data from weather stations on land, satellite measurements of sea surface temperature since 1982, and data from ships for earlier years.

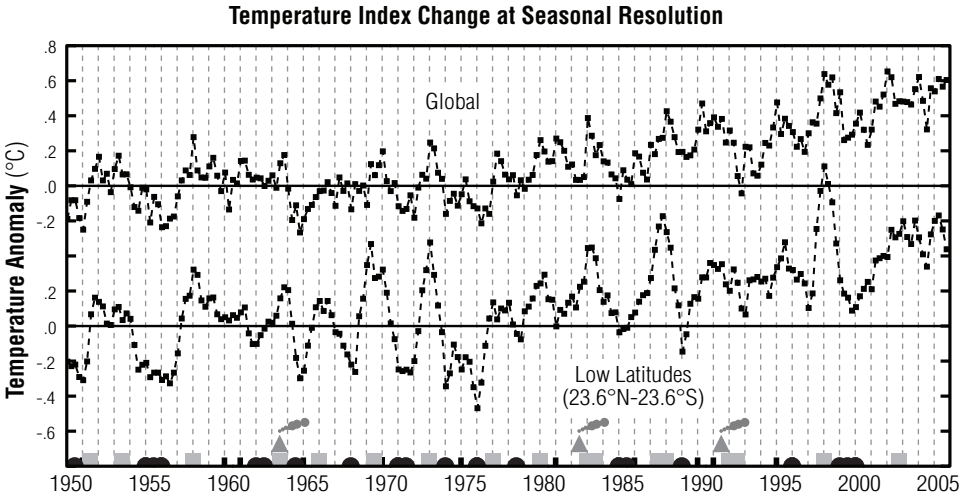
"2007 is likely to be warmer than 2006," said **James Hansen**, Director of NASA GISS, "and it may turn out to be the warmest year in the period of instrumental measurements. Increased warmth is likely this year because an El Niño is underway in the tropical Pacific Ocean and because of continuing increases in human-made greenhouse gases.

Most places on the globe have warmed in recent decades, with the greatest warming at high latitudes in the Arctic Ocean, Alaska, Siberia, and the Antarctic Peninsula. Most ocean areas have warmed. Climatologists say that warming is not due to local effects of heat pollution in urban areas, a point demonstrated by warming in remote areas far from major cities.

In their analysis for the 2005 calendar year, GISS climatologists noted the highest global annual average surface temperature in more than a century. ■



The upper graph shows global annual surface temperatures relative to 1951–1980 mean, based on surface air measurements at meteorological stations, and ship and satellite measurements for sea surface temperature. Over the past 30 years, the Earth has warmed by about 0.6°C (1.08°F). The lower image is a map of temperature anomalies in 2006 relative to the 1951–1980 mean. Areas that were warmest in 2006 are dark, and areas that have cooled are in lighter shades. Note that the Arctic has warmed significantly. These temperatures are for the calendar year 2006.



This graph shows temperature changes since 1950 for both the entire world and just for the low latitudes (23.6° N to 23.6° S). Since 1950, world temperatures rose by 0.6°C (1.08° F) while the low latitude temperatures rose by 0.4°C (0.72°F). Along the bottom, semi-circles mark La Niñas, rectangles mark El Niños, and triangles mark large volcanoes.

NASA Study Finds Warmer Future Could Bring Droughts

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

NASA scientists may have discovered how a warmer climate in the future could increase droughts in certain parts of the world, including the southwest United States.

The researchers compared historical records of the climate impact of changes in the sun's output with model projections of how a warmer climate driven by greenhouse gases would change rainfall patterns. They found that a warmer future climate likely will produce droughts in the same areas as those observed in ancient times, but potentially with greater severity.

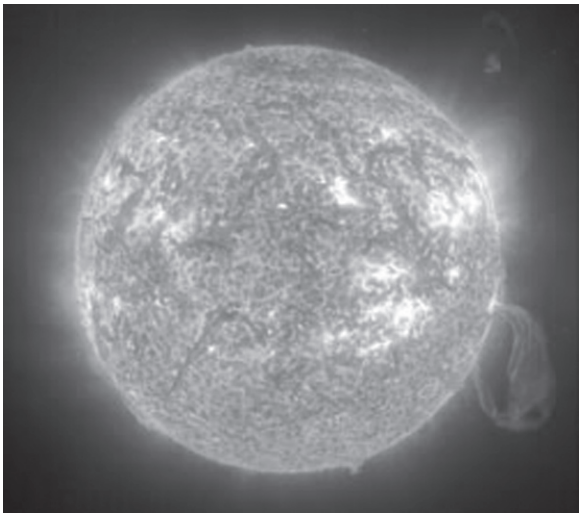
"These findings strongly suggest that greenhouse gases and long-term changes in solar activity both can have major influences on climate via similar processes," said **Drew Shindell**, NASA Goddard Institute for Space Studies, New York. Shindell is lead author of a paper that appeared in the December 27, 2006, issue of the American Geophysical Union's *Geophysical Research Letters.*

"There is some evidence that rainfall patterns already may be changing," Shindell added. "Much of the Mediterranean area, North Africa, and the Middle East are rapidly becoming drier. If the trend continues as expected, the consequences may be severe in only a couple of decades. These changes could pose significant water resource challenges to large segments of the population."

Using the NASA Goddard Institute for Space Studies climate model, researchers found that changes in solar output in the ancient past increased surface warming and altered atmospheric moisture and circulations. These changes likely led to the severe droughts seen in paleoclimate records.

The same model showed that greenhouse-gas warming has similar effects on the atmosphere, suggesting drier conditions may become more common in the subtropics. Rainfall could decrease further in already water-stressed regions such as the southwest U.S. Mexico, parts of North Africa, the Middle East, and Australia. Meanwhile, precipitation may increase across the western Pacific, along much of the Equator, and in parts of southeast Asia.

The computer model considers changes in the weather, the oceans, and the chemistry of the atmosphere—e.g., ozone concentrations—and accurately reproduced the broad rainfall shifts toward regionally drier or wetter conditions during the past several hundred years. Sunspot and ice core data also link the historical rainfall shifts to variations in the amount of energy released by the sun. Since the size of solar changes is uncertain, the study focused on the location and pattern of precipitation shifts, not their precise amount.



Fluctuations in the Sun's output have been linked to changes in the historical climate, and they provide clues as to how global warming could produce droughts in the future. This image of the Sun was taken by NASA's Solar and Heliospheric Observatory in 2001. **Credit:** NASA/GSFC

Increases in solar output break up oxygen molecules, raising ozone concentrations in the upper atmosphere. This adds to upper atmospheric heating that leads to shifts in circulations down to the surface. In turn, surface temperatures warm, and the Earth's basic rainfall patterns are enhanced. For instance, in wet regions such as the tropics, precipitation usually increases, while dry areas become more prone to drought since rainfall decreases and warmer temperatures help remove the small amount of moisture in the soil.

"Precipitation is hard to predict because it is so highly variable, but these results increase our confidence that continued warming will be associated with large-scale changes in rainfall," said Shindell.

Researchers also considered numerous tree-ring, fire, and lake sediment records from across the Americas, including Mexico, Peru, and the Yucatan Peninsula. These data are reliable indicators of historical climate and confirm a pronounced increase in drought frequency in the southern United States, Mexico, and other subtropical locations during periods of increased solar output in the past 1,200 years. This long-term record of solar output is based on chemical isotopes whose production is related to the sun's brightness. Conversely, in parts of the tropics, ocean sediment data, key indicators of precipitation changes, reflect increased rainfall.

According to the researchers, the same processes identified by this new research very likely also affected past civilizations, such as the Pueblo people of New Mexico and Arizona who abandoned cities in the 1300s. ■

NASA Satellites Unearth Clues to Leaks in Antarctic 'Plumbing System'

Gretchen Cook-Anderson, NASA Goddard Space Flight Center, Gretchen.R.Cook-Anderson.1@gsfc.nasa.gov

Imagine peering down from aboard an airplane flying at 35,000 feet and spotting changes in the thickness of a paperback book on a picnic blanket in New York City's Central Park. If you believe this impossible, NASA satellites are doing the equivalent of just that. From nearly 400 miles above the Earth, satellites have detected subtle rises and falls in the surface of fast-moving ice streams on the Antarctic ice sheet, a capability that also offers scientists an extraordinary view of interconnected waterways deep below that surface.

"NASA's satellite instruments are so sensitive we're able to measure from space changes in the ice sheet's surface elevation of a mere three feet," said **Robert Bindschadler**, chief scientist of the Laboratory for Hydrospheric and Biospheric Sciences at NASA's Goddard Space Flight Center, and co-author of a related study published in the February 16 issue of *Science*.

With the aid of the satellites, Bindschadler and a team of scientists led by research geophysicist **Helen Fricker** of the Scripps Institution of Oceanography, revealed a new three-dimensional look at an extensive network of waterways beneath an active ice stream that acts like a natural "plumbing system," and clues to how "leaks" in the system impact the world's largest ice sheet and sea level. They also documented for the first time that changes in the height of the ice sheet's surface prove the lakes and channels below nearly half a mile of solid ice fill and empty.

"This exciting discovery of large lakes exchanging water under the ice sheet's surface has radically altered our view of what's happening at the base of the ice sheet and how ice moves in that environment," said Bindschadler.

Fricker, Bindschadler, and others spotted intriguing discharges of water from the lakes into the ocean. Their research has also delivered new insights into how much water "leaks" from these waterways, how frequently and how many connect to the ocean. Because Antarctica holds about 90% of the world's ice, and 70% of the world's reservoir of fresh water, "leaks" in this system influence sea level and ice melt worldwide.

The research team combined images from an instrument aboard NASA's Terra and Aqua satellites and data from NASA's Ice, Cloud, and land Elevation Satellite (ICESat) to unveil a first-ever view of changes in the elevation of the icy surface above a subglacial lake the size of Lake Ontario that took place over a three-year period. Those changes suggest the lake drained and that its water relocated elsewhere.

To the naked eye, the surface of the ice sheet is very cold and stable, but the base of any of its ice streams is warm, enabling water, melted from the basal ice to flow, filling the system's "pipes" and lubricating flow of the overlying ice. These waterways act as a vehicle for water to move and change its influence on the ice movement, a factor that determines ice-sheet growth or decay.

"There's an urgency to learning more about ice sheets when you note that sea level rises and falls in direct response to changes in that ice," said Fricker. "With this in mind, NASA's ICESat, Terra, Aqua and other satellites are providing a vital public service." ■

A NASA researcher captured this 2005 photo of the Antarctic ice sheet in West Antarctica. NASA satellites are now revealing the "plumbing system" that lies beneath the ice **Credit:** NASA

ESIP Federation Elects 6 New Partners

February 26, 2007—The Federation of Earth Science Information Partners (ESIP) has elected six new partners for full membership. The following represent this strong class of new Federation members:

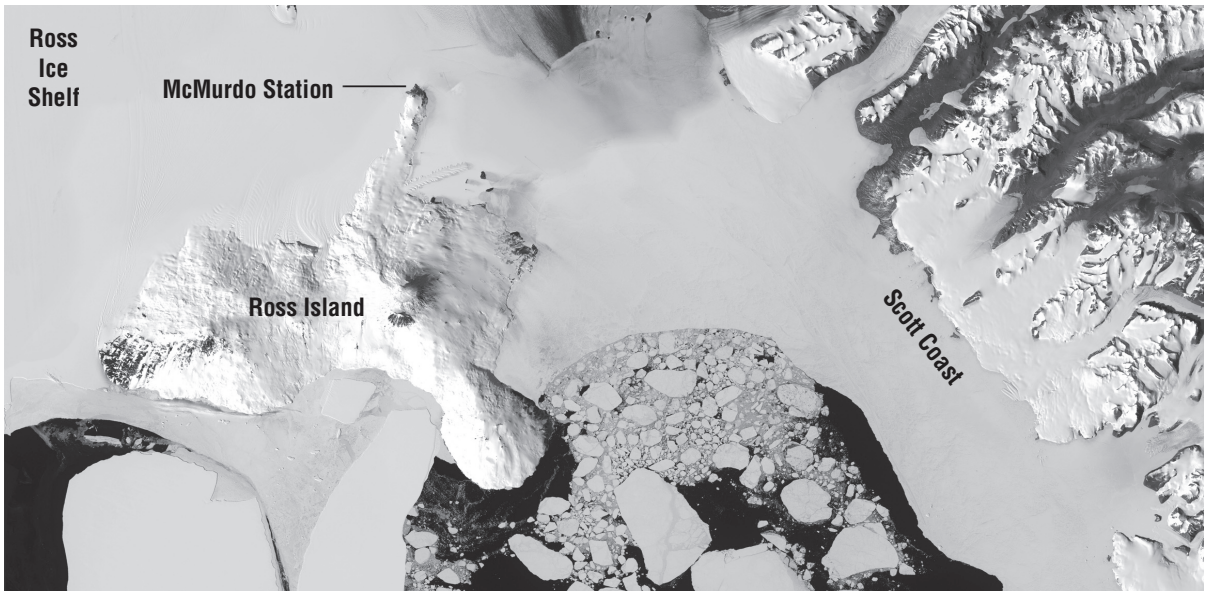
- *Assimilating Aura-derived Trace Gas Retrievals and MODIS AOD into an Operational Multi-pollutant Ensemble Air Quality Forecast Decision Support System with a Focus on Ozone and Haze Prediction*, **John McHenry**, Baron Advanced Meteorological Systems, Raleigh, NC.
- *Global Systems Science Project*, **Alan Gould**, Lawrence Hall of Science, University of California, Berkeley, CA.
- *The HDF Group*, **Mike Folk**, Champaign, IL.
- *NASA Earth Observations*, **Kevin Ward**, Goddard Space Flight Center, Greenbelt, MD.
- *Science Education Resource Center at Carleton College*, **Cathryn Manduca**, Carleton College, Northfield, MN.
- *Virtual Solar-Terrestrial Observatory*, **Peter Fox**, National Center for Atmospheric Research, Boulder, CO.

"The Federation's growth during the past few years has surpassed all expectations," says **Charles Hutchinson**, Federation President. "We are drawing in new partners from a variety of sources, including innovators in the technology and Earth science data management fields. People are drawn to the Federation because of its collaborative environment where partners share cutting-edge ideas to advance the field of Earth System Science and promote a deeper understanding of the Earth system."

The Federation now numbers 103 partners representing a wide range of Earth science data interests. Federation partners include science data centers, environmental research groups, innovators in the application of environmental data, educators, and technologists. Across these diverse interests, public, private, and non-profit organizations are represented.

The Federation is a 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 derivative products. Initiated by NASA in 1997, the Federation provides data products and services to decision makers and researchers in public and private settings. The Foundation for Earth Science provides administrative and staff support to the Federation of Earth Science Information Partners.

The new Landsat Image Mosaic of Antarctica (LIMA) brings the coldest place on Earth alive with a comprehensive view of Antarctica. Over 8,000 scenes were collected from 1999 through 2006 by the Enhanced Thematic Mapper Plus (ETM+) sensor onboard Landsat 7. This image displays a portion of the mosaic over McMurdo Station, the largest research base in Antarctica. Ross Island is roughly 45 miles across at its widest point. For more information and color image see: *landsat.gsfc.nasa.gov/news/news-archive/sci_0008.html.* **Credit:** NASA, U.S. Geological Survey, the British Antarctic Survey, and National Science Foundation.



New MODIS VCF Products Available

New MODIS Vegetation Continuous Fields (VCF) data are now available. Annual percent tree cover is available for 2000 through 2005 globally via the Land Processes Distributed Active Archive Center (DAAC) *lpdaac.usgs.gov* under the product ID *MOD44B*.

These products were generated with MODIS *collection 4* data to replace the version that was created for 2000-2001 with MODIS *collection 3* data. Substantial improvements were made to the underlying surface reflectance product that yield improved estimation of percent tree cover.

Future deliveries in late spring 2007, will include percent herbaceous and percent bare data. An additional delivery near the end of 2007 will show percent needleleaf and broadleaf trees and percent evergreen and deciduous trees. The latter products will be generated every 5 years.

For additional information on product availability contact user services at the LP DAAC. For additional information on the product refer to the User Guide *glcf.umiacs.umd.edu/pdf/MOD44B_User_Guide_v3.0.0.pdf,* or the developers

Matt Hansen *Matthew.Hansen@sdstate.edu*
Kyle Pittman *Kyle.Pittman@sdstate.edu*
Mark Carroll *markc@geog.umd.edu*

These new data sets will also be available through the Global Land Cover Facility (GLCF) *www.landcover.org*. MODIS products through the GLCF are in *GEOTIFF* format with a geographic projection and a tiling system based on Universal Transverse Mercator (UTM) coordinates making it easier to relate these data to Landsat data.

Public Release of Remaining CloudSat Standard Data Products

The CloudSat Data Processing Center (DPC) released a *Beta* version of the final 3 Standard Data Products. These data are now available to the general science community.

It is important for all users to note—and this will be posted on our data ordering site—that these products, as well as all of the CloudSat Standard products in *Release 03*—identified in the filename as "_R03_"—are **provisional** products that are still undergoing validation by the CloudSat Science Team. These products will be superseded by *Release 04* on/about July 2007, and will, at that time, address known issues and other findings from the results of ongoing validation efforts during the remainder of our first year of data collection. In particular, the *CWC*, *TAU*, and *FLXHR* products are only released, at this time, for the period of October 15 - November 15, 2006, to allow the science community to become familiar with them and to do their own quantitative assessment of these initial CloudSat products.

All data users are asked to review the "Known Issues" page of the Data Processing Center website and familiarize yourself with these issues before using the results in publications or presentations. This page is located at *www.cloudsat.cira.colostate.edu/dataIssues.php*. In addition, we ask that you report any additional anomalies or questions to the DPC at: *cloudsat@cira.colostate.edu*.

The on-line product specifications pages are located at: *www.cloudsat.cira.colostate.edu/dataSpecs.php*. In addition, a summary of changes can be found at: *www.cloudsat.cira.colostate.edu/dataConfig.php.*

To access the released data, use the DPC data ordering system interface found at: *cloudsat.cira.colostate.edu/data_dist/OrderData.php*.

If you have any questions concerning the ordering process, contact the DPC at *cloudsat@cira.colostate.edu.*

EOS Scientists in the News

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

Pacific Shows Signs of Morphing From Warm El Niño to Cool La Niña, March 2; *SpaceFlightNow.com, NewsBlaze.com.* Oceanographer **Bill Patzert** (NASA JPL) says new data from NASA satellites show that the tropical Pacific Ocean has transitioned from a warm (El Niño) to a cool (La Niña) condition during the prior two months.

NASA Detects Trends in Rainfall Traits from Drizzles to Downpours, March 2; *United Press International, Terra Daily, Washington Times*. Using a new technique, climatologists including **William Lau** (NASA GSFC) confirm that extremely heavy rainfall in the tropics is indeed on the rise.

NASA Data Link Indonesian Wildfire Flare-Up to Recent El Niño, March 1; *United Press International, Malaysia Sun, Utah Independent.* NASA data has linked the recent El Niño to the greatest rise in wildfire activity in Indonesia since the record-breaking 1997-98 El Niño, finds **David Edwards** (NCAR).

NASA's THEMIS Mission Launched to Study Geomagnetic Substorms, February 17; *SpaceRef.com, Lincoln Tribune*. NASA successfully launched a spacecraft that will help resolve the mystery of what triggers geomagnetic substorms, atmospheric events visible in the Northern Hemisphere as a sudden brightening of the Northern Lights, said **Vassilis Angelopoulos** (University of California-Berkeley).

Joint NASA Study Reveals Leaks In Antarctic 'Plumbing System', February 15; *Associated Press, Reuters, Washington Post*. **Robert Bindschadler** (NASA GSFC) and **Helen Fricker** (Scripps Institution of Oceanography) used NASA satellites to discover an extensive network of waterways beneath a fast-moving Antarctic ice stream that provide clues as to how "leaks" in the system impact sea level and the world's largest ice sheet.

NASA Study Finds Warmer Future Could Bring Droughts, February 12; *United Press International, Washington Times, Science Daily*. **Scientists Drew Shindell**, **Greg Faluvegi**, **Ron Miller**, **Gavin Schmidt**, and **James Hansen** (NASA GISS) may have discovered how a warmer climate in the future could increase droughts in certain parts of the world, including the southwest United States.

2006 Was Earth's Fifth Warmest Year, February 8; *USA Today, RedOrbit.com.* Using a variety of data, climatologist **James Hansen** (NASA GISS) finds that 2006 was the fifth warmest year in the past Century.

Satellites and Sea Lions: Working Together to Improve Ocean Models, February 6; *SpaceRef.com.* Electronic sensors are not only tracking the movement of sea creatures, they are also gaining valuable information on ocean conditions that can be used to improve ocean models, say scientists **Yi Chao** (NASA JPL), **Dan Costa** (University of California-Santa Cruz), and **Barbara Block** (Stanford University).

A NASA Space Sleuth Hunts the Trail of Earth's Water, January 31; *SpaceRef.com, PhysOrg.com.* For the first time, scientists including **John Worden** (NASA JPL), **Kevin Bowman** (NASA JPL), and **David Noone** (University of Colorado-Boulder) are tracking the origin and movement of water vapor throughout Earth's atmosphere by using the Tropospheric Emission Spectrometer instrument on the Aura satellite.

NASA Probes the Sources of the World's Tiny Pollutants, January 30; *Science Daily, Terra Daily, Innovations Report.* A team of scientists led by **Dorothy Koch** (NASA GISS) used NASA data to track the path and distribution of aerosols to link their region of origin and source type with their tendencies to warm or cool the atmosphere.

Airborne Dust Causes Ripple Effect on Climate Far Away, January 25; *United Press International, Science Daily, Terra Daily.* NASA researchers, including **Bill Lau** (NASA GSFC), have found that aerosols can cause a rippling effect on the climate thousands of miles away from their source region.

The 2006 Hurricane Season Was Near Normal, January 18; *United Press International, KFTY-TV (San Francisco).* After the record-setting hurricane season of 2005, **Scott Braun** (NASA GSFC), **Bill Patzert** (NASA JPL), and **Jeffrey Halverson** (University of Maryland-Baltimore County) determined why conditions in 2006 led to a relatively benign season.

A Tale of Two Sites: Impacts of Relocating L.A.'s Weather Station, January 17; *Associated Press, Fresno Bee, San Jose Mercury News*. The official Los Angeles weather station was moved from downtown to the University of Southern California in 1999 and a recent study shows the move resulted in a significant decrease

in measured temperatures and precipitation, finds **Bill Patzert** (NASA JPL).

THEMIS Will Judge What Causes Highly Dynamic Aurora, January 17; *Space Daily.* A fleet of NASA space instruments, called Time History of Events and Macroscale Interactions during Substorms (THEMIS), will study the trigger mechanisms for magnetospheric storms and provide new insight into aurora, say **David Sibeck** (NASA GSFC) and **Vassilis Angelopoulos** (University of California-Berkeley).

El Niño Seen Fading, But Jury Still Out, January 16; *Reuters, Scientific American.* The current El Niño weather anomaly appears to be fading, say scientists including **Bill Patzert** (NASA JPL), and its impact has been muted in North America with normal weather conditions over much of the Midwest United States.

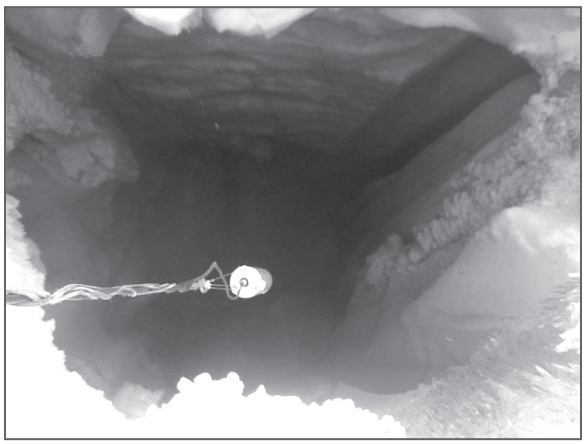
Temperatures Drop Below Freezing in Much of California, January 13; *Associated Press, Los Angeles Times, CBS Evening News.* **Bill Patzert** (NASA JPL) discusses the cause of a prolonged cold snap in much of California that brought snow, freezing temperatures, and considerable damage to the orange industry.

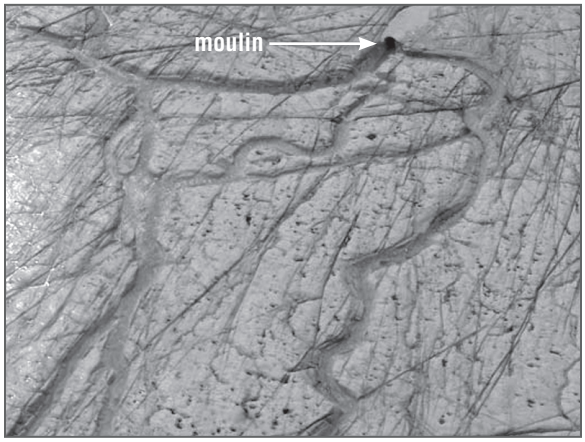
Goddard Team Honored for Achievements in Remote Sensing, December 14; *SpaceRef.com.* NASA's Total Ozone Mapping Spectrometer team won the 2006 William T. Pecora Award for significant achievements in remote sensing, and **Rich McPeters** (NASA GSFC) says the sensors have provided some of the most influential environmental data ever produced, documenting the emergence and development of the Antarctic ozone hole.

NASA Ice Images Aid Study of Pacific Walrus Arctic Habitats, December 12; *Biology Daily, Science Daily.* Research scientists **Jay Skiles** (NASA ARC) and **Cynthia Schmidt** (NASA ARC) recently collaborated with the Fish and Wildlife Service to determine the usefulness of satellite imagery for studying the effect of climate change on the Pacific walrus ice habitat in Alaska.

Moulin 'Blanc': NASA Expedition Probes Deep Within a Greenland Glacier, December 11; *RedTram.com.* Scientist Alberto Behar (NASA JPL) recently led an expedition to send a NASA-built probe into the glacial chutes in the remote and isolated Pakisoq region of the West Greenland Ice Sheet.

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.* ■





Moulin 'Blanc': NASA Expedition Probes Deep Within a Greenland Glacier
A *moulin* is a narrow, tubular shaft in a glacier that provides a pathway for water to travel from the glacier's surface to its bottom. **Alberto Behar** of NASA's Jet Propulsion Laboratory and co-investigator **Konrad Steffen** of the University of Colorado, Boulder, led an expedition to send a JPL-built probe down into these glacial chutes in the remote and isolated Pakisoq region of the West Greenland Ice Sheet. That dynamic area of Earth's northern polar region is not well understood and is responding rapidly to climate change. Previous NASA measurements there using global positioning system data show the ice there moves an average of about 20 cm (8 in) a day, accelerating to about 35 cm (14 in) a day during the summer melt. The scientists set out to see if these moulins, or pathways, within and beneath these mountains of ice can shed new light on how glacial water flows from the ice sheet to the sea. (*left*) The probe is lowered into the moulin. (*right*) An aerial view showing water converging on the moulin. For color images and full story visit: *www.nasa.gov/vision/earth/lookingatearth/moulin-20061211.html.* **Image Credits:** NASA/JPL.

NASA Science Mission Directorate – Science Education Update

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FREE PUBLIC LECTURES BY NASA EARTH SCIENTISTS (LIVE AND ONLINE)

NASA Goddard Space Flight Center and The Library of Congress announce free public presentations by top NASA scientists on current topics such as climate change, urban sprawl, and natural disasters. For those unable to attend the event in person, the lectures will be available after the event at *www.loc.gov/rr/scitech/*. Here is the schedule of upcoming presentations:

April 3 - *Honey Bees, Satellites, and Climate Change*. Wayne Esaias, Ocean Sciences Branch, NASA GSFC
June 27 - *City Lights, Spy Satellites, and Urban Sprawl*. Marc Imhoff, Terra Project Scientist, NASA GSFC
October 17 - *Predicting, Observing, and Mitigating Damage from Fires and Other Natural Disasters*. NASA presenter TBA

EARTH EXPLORATION TOOLBOOK: ANALYZING THE ANTARCTIC OZONE HOLE

The Antarctic ozone hole is bigger than ever according to scientists from NASA and the National Oceanic and Atmospheric Administration (NOAA). *Analyzing the Antarctic Ozone Hole*, a chapter of the Web-based Earth Exploration Toolbook, provides the guidance and tools necessary for middle and high school students to perform their own studies of the ozone hole using data collected by the Total Ozone Mapping Spectrometer (TOMS) instrument. See *www.nasa.gov/audience/foreducators/5-8/features/F_Analyzing_Antarctic_Ozone_Hole.html*

EDUCATOR'S ANTARCTIC JOURNALS AVAILABLE ONLINE
www.polartrec.com/allanmillerjournal

Allan Miller, Albert Einstein Distinguished Educator Fellow at the National Science Foundation and a NASA Educator Astronaut finalist, has returned from a tour of duty in and around Antarctica. Miller chronicled his experience in an expedition—the first of at least 30—that allows classroom teachers to travel to field research sites in the Arctic and Antarctic and work with scientists engaged in many different types of polar research throughout the upcoming International Polar Year (IPY) 2007-2009.

COSEE-SE's COASTAL PROCESSES IN THE OUTER BANKS WORKSHOP
June 25-29, 2007, Manteo, N.C.

Coastal Processes in the Outer Banks is a free workshop offered as part of the *Coastal Legacy: Multicultural Marine Science*, Professional Development Summer Program from the Center for Ocean Sciences Education Excellence-SouthEast (COSEE-SE). Participants will explore the physical forces that create barrier island dynamics. By investigating regional geology, currents, waves and weather, educators will learn how researchers use technology to measure the processes and enhance their Earth science and physical sciences classes. Applications will be accepted from middle and high school teachers, pre-service teachers, and informal educators in North Carolina, South Carolina, and Georgia; teachers in schools with high percentages of underrepresented/underserved populations are encouraged to apply. Contact Elizabeth Joyner, *elizabeth.joyner@scseagrant.org*. Information and applications will be available at *www.scseagrant.org/se-cosee/*.

TEACHER TO RANGER TO TEACHER

The National Park Service offers its visitors meaningful experiences to learn and explore in its parks, but unfortunately, not everyone can visit a park to take advantage of these opportunities. The *Teacher to Ranger to Teacher Program* strives to reach out to those in the underserved urban and rural school districts and bring a piece of the park to them. The teachers in this program spend the summer working as a park ranger. Teachers develop lesson plans drawing from their summer work and when they return to the classroom, they are able to engage students with a new perspective from this unique summer experience. Please visit *www.nps.gov/wupa/forteachers/trt.htm* for more information.

EPA ANNOUNCES NEW CLIMATE CHANGE KIT FOR HIGH SCHOOL STUDENTS

Climate CHECK is a free, *Excel*-based kit that teaches high school students about the science, drivers, and impacts of climate change and provides them with knowledge, tools, and resources to increase climate-change awareness and to help them reduce greenhouse gas emissions at their school. Using *Climate CHECK*, students will estimate greenhouse gas emissions using built-in calculators and school-specific "activity data"

and develop and implement a mitigation action plan. To download *Climate CHECK*, go to *www.epa.gov/climatechange/wycd/school.html.*

SEISMAC: TURN YOUR MAC INTO A SEISMOGRAPH
www.suitable.com/tools/seismac.html

Suitable Systems offers free software that transforms a G4 Macintosh laptop into a seismograph with real-time acceleration information displayed on the screen. Tap your toe on the floor beneath the table holding a laptop and watch the seismic waves appear. Activities are currently being developed to go along with this tool.

NOVA FEATURES SPACE-BASED RESEARCH ON THE MAYA

This broadcast of NOVA *scienceNOW* features the work of NASA space archaeologist **Tom Sever** and his colleague **Bill Saturno** of the University of New Hampshire who used Earth-orbiting satellites to find ancient Mayan ruins in Guatemala. For details, visit: *www.pbs.org/wgbh/nova/sciencenow.* Viewers can watch the complete episode online at: *www.pbs.org/wgbh/nova/sciencenow/3401/03.html.* This page includes a teachers guide and links to other useful resources related to this episode of NOVA *scienceNOW*. ■

MISR Level 3 netCDF Products to Support Climate Modeling Community

The NASA Langley Research Center Atmospheric Science Data Center (ASDC) and the NASA Jet Propulsion Laboratory (JPL) MISR teams announce the release of MISR Level 3 netCDF products. These Network Common Data Form (netCDF) file format data were designed specifically to support the climate modeling community.

These MISR Level 3 products provide a global summary of Level 1 and Level 2 data. MISR Level 1 and Level 2 parameters are averaged over a day, month, season, or year, and the results reported on a geographic grid, with resolution 0.5° by 0.5°, 1° by 1°, 2.5° by 2.5°, or 5° by 5°, depending on the product. These products are the same format as the HDF-EOS products except there is one file for each grid resolution.

Products available are:

- Component Global Land Surface Product (CGLS)
- Component Global Aerosol Product (CGAS)
- Component Global Albedo Product (CGAL)
- Component Global Cloud Product (CGCL)

Example file name: MISR_AM1_CGCL_0_5_DEG_JUN_01_2003_F02_0020.nc

The netCDF products are available through the MISR Order and Customization Tool (Step 1) at: *l0dup05u.ecs.nasa.gov/MISR/cgi-bin/MISR/main.cgi*

HOW TO CONTACT US:

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

Atmospheric Science Data Center
NASA Langley Research Center
Users and Data Services
Mail Stop 157D, 2 S. Wright Street Hampton, VA 23681-2199
Phone: 757-864-8656
E-mail: *larc@eos.nasa.gov*
Web site: *eosweb.larc.nasa.gov*

EOS Science Calendar

April 24-26
CERES Science Team Meeting, Newport, News, VA, Contact: Sashi Gupta, *S.K.Gupta@larc.nasa.gov*

May 30-June 1
AVIRIS Science Workshop, Pasadena, CA.
URL: *aviris.jpl.nasa.gov*

June 12-14
Landsat Science Team Meeting, Corvallis, OR. Contact: Thomas Loveland, *Loveland@usgs.gov*

October 1-5
Aura Science Team Meeting, Pasadena, CA.
URL: *aura.gsfc.nasa.gov*

October 22-25
A-Train Lille Symposium 2007, Lille Grand-Palais, France. URL: *www.a-train-lille2007.org*

Global Change Calendar

May 21-23
IEEE 3rd International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities, Orlando, FL. URL: *www.tridentcom.org/*

May 22-25
2007 Joint Assembly of the American Geophysical Union (AGU), Acapulco, Mexico. URL: *www.agu.org/meetings/ja07/*

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*

June 4-8
2007 International Waveform Diversity & Design Conference, Pisa, Italy. URL: *www.waveformdiversity.org*

June 6-8
The Second International Conference on Scalable Information Systems, Suzhou, China.
URL: *www.infoscale2007.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*

July 2-13
XXIV IUGG General Assembly, Perugia, Italy.
URL: *www.iugg2007perugia.it/*

July 9-13
14th Bi-Annual Coherent Laser Radar Conference, Snowmass, CO. URL: *space.hsv.usra.edu/CLRC*

July 23-27
International Geoscience and Remote Sensing Symposium (IGARSS), Barcelona, Spain. URL: *www.grss-ieee.org/menu.taf?menu=conferences&detail=igarss*

August 6-10
4th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services.
URL: *www.mobiquitous.org*

August 20-24
First International Circumpolar Conference on Geospatial Sciences and Applications, Yellowknife, N.W.T., Canada. URL: *ess.nrcan.gc.ca/ipygeonorth/index_e.php*

August 22-24
Second International Conference on Access Networks, Ottawa, Ontario, Canada. URL: *www.accessnets.org/2007/*

August 26-30
Earth Observing Systems XII (OP400), San Diego. URL: *spie.org/Conferences/Calls/07/op/oea/index.cfm?fuseaction=OP400*

August 27-29
2007 IEEE International Workshop on Machine Learning for Signal Processing (formerly IEEE Workshop on Neural Networks for Signal Processing), Thessaloniki, Greece. URL: *mlsp2007.conwiz.dk/*

August 29-31
The Third International Symposium on Information Assurance and Security (IAS'07), Manchester, UK.
URL: *www.ias07.org/*

September 5-7
1st Annual OceanTech Expo, Providence, RI.
Contact: Rob Howard, *Howard@marinelink.com*

September 17-21
Third International Conference on Security and Privacy for Communical Networks, Nice, France. URL: *www.securecomm.org*

October 17-19
First International Conference on Networks for Grid Applications, Lyon, France. URL: *www.gridnets.org/2007*

October 28-30
First International Conference on Autonomic Computing and Communication Systems, Rome, Italy.
URL: *www.autonomics-conference.eu/*

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