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# Editor's Corner

*Michael King*
*EOS Senior Project Scientist*

I'm happy to report that The Earth Observer is beginning its 20th year as a NASA publication. The first issue was released in March 1989, and from the beginning, it has been dedicated to keeping our readers abreast of the latest developments in the Earth Observing System (EOS) program. I have been pleased to serve as EOS Senior Project Scientist since September 1992, and thus have been around for most of The Earth Observer's 20-year history. It has been my privilege to work with a wide variety of talented individuals over the years who have made contributions to the publication as authors, designers, editors, etc. The names are too many to list, but I would particularly like to recognize the members of the current EOS Project Science Office who are involved. **Alan Ward** (Executive Editor) and **Charlotte Griner** (former Executive Editor) thoroughly review the content of every issue and are constantly on the lookout for interesting articles for future issues. **Tim Suttles**, and **Chris Chrissotimos** also serve as Technical Editors and review each issue. **Debbi McLean** does the layout of the newsletter and handles the production of each issue. **Cindy Trapp** and **Leon Middleton** help with the distribution of each issue. **Steve Graham** maintains a database that keeps track of over 6000 subscribers. PDFs of every issue from 1995 to the present are posted on the EOS Project Science Office website that **Maura Tokay** maintains—*eospso.gsfc.nasa.gov/eos_homepage/for_scientists/earth_observer.php.* (Archived hard copies of all issues are also on file in the EOSPSO library.) The publication is and always has been a true team effort from start to finish.

To the current staff and to every individual that has contributed to making *The Earth Observer* such a top-notch publication for so many years, I say: "Congratulations and keep up the outstanding work!" On page 4 of this issue our Executive Editor has written an article sharing his perspective on *The Earth Observer*'s important role in compiling a written history of the EOS program and its ongoing role in communicating news about the pro-

continued on page 2

A model of Explorer 1, held by JPL's Director William Pickering, scientist James Van Allen and rocket pioneer Wernher von Braun (from left to right). America's first satellite, Explorer 1 had launched a few hours before, on January 31, 1958, at 10:48 p.m. EST. **Credit:** NASA

the earth observer

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gram to our readers. As the year progresses, we will try to bring you additional perspectives on 20 years of *The Earth Observer* and on the life of EOS from people who were there from the beginning.

On March 21, **David Herring** accepted an offer from NOAA to serve as Communications Program Administrator within their Climate Program Office based in Silver Spring, MD. Herring has a long history with the EOS Program, having worked at Goddard Space Flight Center since June 1992, and serving for most of that time as a contractor with Science Systems and Applications Incorporated (SSAI). Herring began his employment at NASA as a science writer on the Moderate Resolution Imaging Spectroradiometer (MODIS) Administrative Support Team. In 1997, Yoram Kaufman promoted Herring to the role of Terra Outreach Coordinator, and it was under Kaufman's leadership that Herring founded NASA's *Earth Observatory* (*earthobservatory.nasa.gov*) in April 1999. He also spearheaded development of a family of related sites that have grown up around the Earth Observatory. Herring's team has garnered numerous awards, including two NASA Group Achievement Awards, citations by *Scientific American* and *Popular Science*, and three prestigious *Webby Award* nominations. In 2006, Herring was awarded the NASA Exceptional Achievement Medal. He attributes the success of *The Earth Observatory* and related sites to the excellent core team based at Goddard—which will remain intact after his departure—that has been guided and nurtured by the outstanding ideas and stunning data contributions from across the entire NASA Earth Science community.

Herring was a civil servant in his last three years at NASA, reporting to Michael Seablom within the Software Integration and Visualization Office (SIVO), as the Goddard Earth Sciences Division's Project Manager for Education and Public Outreach. In that time, he completed a 7-month detail as Outreach Program Manager in the Earth Sciences Division at NASA Headquarters. I wish Herring well in his new endeavor and look forward to working with him in his new capacity at NOAA.

I'm also pleased to report that on February 4, NASA announced the start of the Soil Moisture Active-Passive (SMAP) and the Ice, Cloud and land Elevation Satellite-II (ICESat-II) missions. SMAP will provide high-resolution global maps of soil moisture for early warning of droughts, improved weather and climate forecasts, and predictions of agricultural productivity. ICESat-II will precisely measure the heights of ice sheets and sea-ice thickness, and provide estimates of above-ground forest and vegetation biomass. These two missions were top priorities of the National Research Council's Decadal Survey of Earth Science and Applications from Space, which was issued in 2007. SMAP is being planned for a launch in 2012, followed by the launch of ICESat-II in 2015.

The President's FY'09 budget request provides $570 million over the next five years for the development of the many Decadal Survey recommendations, including SMAP and ICESat-II, conducting early development work on three or more additional Decadal Survey missions, and initiating some smaller *Venture* class activities. It also continues funding for the Ocean Surface Topography Mission (OSTM), Orbiting Carbon Observatory (OCO), Glory, Aquarius, National Polar-orbiting Operational Environmental Satellite Preparatory Project (NPP), Landsat Data Continuity Mission (LDCM), and Global Precipitation Measurement (GPM) mission, all scheduled for launch between 2008 and 2014. The budget also provides funds for operation and data production of 13 on-orbit missions in their prime or extended phases, and transfers funding for studies of Near-Earth Objects and the Education and Outreach Program into the Earth Science Research Program. I consider these developments encouraging signs for the future of Earth science and opportunities to build on the legacy of the Earth Observing System.

January 31, 2008 marked the 50th Anniversary of the very first U.S. satellite launch. Following the launch of the Soviet Union's *Sputnik 1* on October 4, 1957, the U.S. Army Ballistic Missile Agency was directed to launch a satellite using its *Jupiter C* rocket developed under the direction of German scientist Werner von Braun, who surrendered to the U.S. at the end of World War II. The Jet Propulsion Laboratory (JPL) received the assignment to design, build and operate the artificial satellite called *Explorer 1* that would serve as the rocket's payload. JPL completed this job in less than three months—talk about quick delivery!

The primary science instrument on *Explorer 1* was a cosmic ray detector designed to measure the radiation environment in Earth orbit. Once in space this experiment, provided by James Van Allen of the University of Iowa, revealed a much lower cosmic ray count than expected. Van Allen theorized that the instrument might have been saturated by very strong radiation from a belt of charged particles trapped in space by Earth's magnetic field. The existence of these radiation belts was confirmed by another U.S. satellite launched two months later, and they became known as the Van Allen Belts in honor of their discoverer. *Explorer 1*'s signal lasted for about four months, ending on May 23, 1958, when the batteries failed. The satellites remains burned up over the Pacific Ocean as it entered Earth's atmosphere on March 31, 1970. Many more details about *Explorer 1*, including images and video and audio clips can be found at the JPL Website: *www.jpl.nasa.gov/explorer.*

In addition to that milestone, January 12, 2008, marked the 5th Anniversary of the ICE, Clouds, and land Elevation Satellite (ICESat). Measurements from the Geoscience Laser Altimeter System (GLAS) on ICESat can measure the distance from the spacecraft to the ice sheet to within 10 cm or less of its actual value. These extremely precise measurements have helped us to determine variations of ice-sheet elevation over time on both Greenland and Antarctica, and helped answer long-standing questions about whether the ice sheets, which contain 8% of all freshwater on Earth, are gaining or losing mass. I would like to extend my congratulations to ICESat Project Scientist, **Jay Zwally**, and to everyone else who has worked hard to make ICESat a successful mission, and helped to lay a firm scientific foundation for the upcoming ICESat-II mission.

Finally, I would like to announce that I will be retiring from NASA after 30 years of service, the last 15 ½ years as EOS Senior Project Scientist, during which time I had the good fortune to work with an extraordinary array of scientists from the emerging field of Earth system science, including terrestrial ecologists, atmospheric scientists, physical and biological oceanographers, hydrologists, cryosphere scientists, and countless other scientists, engineers, visualizers, science writers, and data system specialists, who have shared my passion in quantitative observation, monitoring, and exploration of Earth from space. Through this period of development, restructuring, budget reviews, scrutiny of Congress and the Administration, and technical challenges from rocketry to instrument development, we have managed to develop a premier Earth observing system that continues to provide scientific observations of importance to people the world over. We have not done this alone, as many of our 10 EOS satellites launched over the past 10 years have involved instruments or spacecraft of partners from Canada, Russia, Japan, France, the United Kingdom, Brazil, the Netherlands, and others. Though I will be leaving NASA at this time, I will continue my career as a senior research scientist in the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, and will continue my close association with EOS through participation in the MODIS Science Team on Terra and Aqua, as well as countless field experiments that are regularly conducted to validate data from these space assets.

While the future role and scope of the Project Science Office is being reviewed in relation to the implementation of the missions suggested in the NRC Decadal Survey, I am pleased to announce that **Steven Platnick** will perform my responsibilities as EOS Senior Project Scientist. He will continue his research in clouds and radiation as a member of the MODIS Science Team on Terra and Aqua as well as a member of the CloudSat Science Team. He has served for the last 5 years as Deputy Project Scientist of Aqua, including active participation in the successful Senior Review of Aqua that was conducted last year. Platnick came to NASA with a broad background in both Electrical Engineering, where he worked at Hewlett-Packard (now Agilent), and Atmospheric Sciences, where he received his Ph.D. from the University of Arizona. Following a post-doc at NASA Ames Research Center, he came to the University of Maryland and later Goddard where he has played a pivotal role in developing the MODIS cloud optical properties algorithm for the past 15 years. Very best wishes to Platnick and all my EOS Project Science Office colleagues for the continued success of the office. And finally, a special note of appreciation and great admiration to all of the mission project scientists for their hard work and support over many years. ▬

# The Earth Observer: 20 Years Chronicling the History of the EOS Program

*Alan B. Ward, Executive Editor, Earth Observer Newsletter, NASA Goddard Space Flight Center, award@sesda2.com*

March 2008 marks the beginning of the 20th year of *The Earth Observer* newsletter. The first issue was published in March 1989 and was intended to be a *"periodical of timely news and events,"* to keep readers abreast of new developments in the rapidly evolving Earth Observing System (EOS) Program. EOS management was originally shared between NASA's Goddard Space Flight Center (GSFC) and the Jet Propulsion Laboratory (JPL). The original Executive Editors were **JoBea Camino** [JPL] and **Darrel Williams** [GSFC]. In late 1989, after a Non-Advocate Review of EOS, program management was consolidated at Goddard. At that time, the EOS Project Science Office, which had originally been created to oversee the early stages of the program, took sole responsibility for the publication of *The Earth Observer*. (A new masthead was developed to reflect this change.) **Charlotte Griner** served as Executive Editor from late 1989 until 2005, when I (**Alan Ward**) took over.

As I read through the archived copies of back issues of *The Earth Observer*, two things stood out to me: 1) *The Earth Observer* is a chronicle of the ongoing history of the EOS Program; and 2) technology has certainly come a long way since our publication began.....but *The Earth Observer* continues to be an effective and valuable tool for communicating news about EOS.

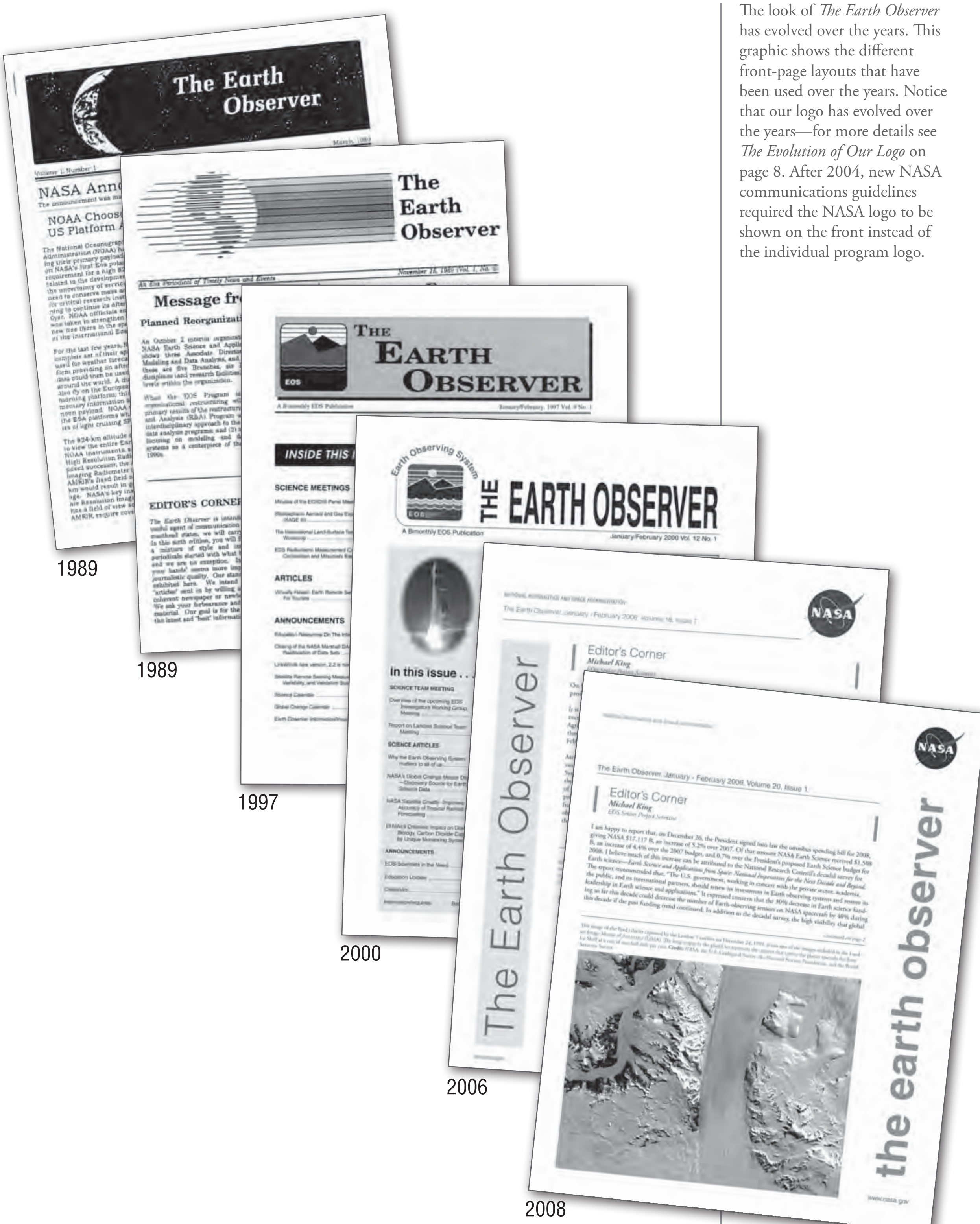
*The EOS Program has a long and rich history and **The Earth Observer** has been there to report much of that history.*

The EOS Program has a long and rich history and *The Earth Observer* has been there to report much of that history. When the first issue was published in 1989, EOS was in its infancy. NASA, the European Space Agency, and the National Space Development Agency (NASDA) of Japan had released a joint Announcement of Opportunity a year earlier, and the NASA selections for EOS platforms and instruments had just been made. The big news in that first issue was NOAA's decision not to place science instruments on the planned school bus-sized NASA EOS platforms, as well as an announcement of the first gathering of those selected to be NASA EOS investigators—what would become known as the EOS Investigators Working Group (IWG) that would continue to meet through 2002.

We've come a long way since those early days and the spacecrafts that actually ended up in orbit are not like those originally envisioned. Budget cuts and other programmatic changes and directives over the years have resulted in many alterations from the original concept, and our newsletter has remained dedicated to keeping you up to date.

The *Editor's Corner* has been a regular feature of *The Earth Observer* almost from the beginning. The column began in September 1989 (*Volume 1, Issue 5*) and rapidly evolved into a venue for the EOS Senior Project Scientist to report on the latest happenings from around the program. Since getting a *new start* in late 1990 as part of *Mission to Planet Earth*, EOS has been restructured, rebaselined, reshaped, and thoroughly reviewed on several occasions, mostly in response to changes in the program's funding levels—see *The Plans Have Changed…but EOS Remains* at the end of this article.

As I skimmed through each issue, I got a good sense of the historic context of these different events and a better appreciation for the tumultuous early history of EOS. I began to understand why the scientists who have been involved with the EOS Program for decades have such passion for what they do. In the face of many obstacles, these men and women persevered and refused to give up on the vision of creating a true *Mission to Planet Earth*—a fleet of Earth observing satellites that would help us determine how the Earth was changing and what the consequences of those changes were for life on our home planet. Through the early to mid-1990s, at numerous IWG, Payload Panel and Instrument Panel meetings, they put in long hours of deliberation




The look of *The Earth Observer* has evolved over the years. This graphic shows the different front-page layouts that have been used over the years. Notice that our logo has evolved over the years—for more details see *The Evolution of Our Logo* on page 8. After 2004, new NASA communications guidelines required the NASA logo to be shown on the front instead of the individual program logo.

and debate on how to make the hopeful vision of EOS a reality. No doubt they had many frustrations along the way as they had to continually go *back to the drawing board* and reconfigure the plans for the program in the face of continuing budget cuts and the recommendations of other programmatic reviews.

Their hard work and dedication is now beginning to pay off, however, as all of the EOS missions are now in orbit. The information these satellites collect is indeed revolutionizing our understanding of the health of our planet and the implications for society, and laying the groundwork for future missions to continue what EOS began.

*In those early years in particular,* ***The Earth Observer*** *was a vital pathway for communication of the latest news about EOS.*

The *Editor's Corner* has also chronicled programmatic and personnel changes over the years—see *The Names Have Changed… but EOS Remains* at the end of this article. Since EOS began, three individuals have served as EOS Senior Project Scientist[1]—**Gerald "Jerry" Soffen** (1989-1990), **Jeff Dozier** (1990-1992), and **Michael King** (1992-2008). Shortly after King took over in September 1992, he began an effort to reorganize the office so that key Earth scientists serve as Project Scientists for each individual mission (a structure that remains to the present) and initiated regular meetings with these Project Scientists to stay abreast of important issues impacting each mission. The *Editor's Corner* has reported those developments that were newsworthy and also reported each time there has been a change or addition to King's staff as well as other changes at Goddard and at NASA Headquarters over the years—particularly those relevant to EOS.

Beyond the *Editor's Corner*, the articles contained in these back issues are a virtual treasure trove of written history of the program. Contained in the pages of those old newsletters are detailed summaries of all of the IWG Meetings, Payload Panel Reviews, Instrument Team Meetings, and Science Team Meetings that have taken place over the years. There are also reports on many other meetings, research projects, field campaigns, Earth science news stories, educational updates, etc. Many of these meetings (especially during the 1990s) were where important decisions were made that would shape (or often reshape) the EOS program into what it has become today.

The other thing I observed as I looked through *The Earth Observer* archives is that technology has evolved tremendously in the 20 years this publication has existed, but the publication is still an important means of communicating information about the program. Now, in 2008, it's easy to forget that there was a time not long ago that e-mail and the internet were not always commonplace, which was the case back in 1989. The very first issue contained an advertisement that said one could view old issues by logging into the *JPL VAX* by following what would today be considered a cryptic set of instructions; it also indicated that input for the newsletter had to be sent to the editors by *telemail*. In 1992, an EOS electronic bulletin board was established. The EOS Project Science home page was created in 1994—accessible via *Mosaic*—and began to grow rapidly as the internet became more and more widespread. Archived newsletters, Payload Panel Reports, algorithm theoretical basis documents, etc. were made available at the site, and soon brochures, fact sheets, lithographs, reference handbooks, and other outreach products promoting EOS missions and instruments began proliferating. E-mail addresses similar to those we have today started appearing on a regular basis in *The Earth Observer* after about 1994; before that it was more common to see telephone numbers and *snail mail* addresses listed for contacting authors.

In those early years in particular, *The Earth Observer* was a vital pathway for communication of the latest news about EOS. The EOS Project Science Office staff put lots of effort into keeping an up-to-date database so that everyone who wanted to stay informed about EOS could do so. Nowadays, the website— *eospso.gsfc.nasa.gov*—is used to communicate the latest news and PDFs of every issue can be downloaded. But I am struck by the fact that **even with all our technology, people still like to receive a print copy of their newsletter**. At last count, we have over 6000 subscribers to the newsletter and we frequently receive feedback indicating that people still look forward to receiving and enjoy reading *The Earth Observer*.

Clearly, **much** has changed in 20 years as *The Earth Observer* has gone through several redesigns. The format we use today looks quite a bit more polished than that first issue——see graphic on page 5 to see how the look has changed over the years—but certain elements have been there from the very beginning. Back then it was more critical to get the information out than have it perfectly formatted. As the EOS program has matured and all of the missions have now been launched and are sending back

[1] Originally, the position was referred to simply as *EOS Project Scientist*.

data, we've been able to broaden our focus from reporting almost entirely on the planning and implementing of EOS to reporting on interesting EOS research results and societal applications stemming from Earth science research. We've also placed more emphasis on reporting about news, education, and outreach related to Earth science over the years—the Science News and Information Team was established in 1998 to aid that effort. Through all the changes, however, our staff has remained committed to our original vision—slightly modified for the post-EOS era—of reporting on *timely news and events relevant to Earth science at NASA*. That continues to be our goal. I hope you enjoy this issue and the next 20 years…

### *The Plans Have Changed… but EOS Remains*

***Did you know??*** When *The Earth Observer* first hit the streets back in 1989 EOS was envisioned quite a bit different than what we have today, and yet many of the instruments originally envisioned are in orbit today.[1]

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Two NASA Polar Orbiting Platforms (NPOP) (called EOS A and EOS B) were proposed to go along with European Space Agency's European Polar Orbiting Platform (EPOP) and the Japanese Space Development Agency's (NASDA) Japanese Polar Orbiting Platform (JPOP). Both EOS A and EOS B were envisioned as having an afternoon orbit (1:30 Equator crossing time) with the EPOP having a morning orbit. NOAA had considered putting a complete set of its spaceborne instruments on the first polar platform giving an afternoon view of Earth, and a duplicate set on EPOP for morning coverage. The problem was that the NOAA instruments would've required an orbit of 824 km instead of the 700 km orbit that NASA preferred. NOAA instead decided to fly their primary payloads as *free flyers* citing the developmental nature of the program, the uncertainty of servicing technologies, and the need to conserve mass and real estate on the platform. NOAA viewed any new *free flyers* launched during the *Space Station Era* as part of EOS. In addition, EOS was to have the opportunity to place a limited number of Earth-viewing instruments as attached payloads on the low-inclination orbiting Space Station *Freedom*—which eventually evolved into the International Space Station we have today.

In 1990, the President's budget request for 1991 included considerable funding for a "new start" for EOS and Earth Probes. The Goddard management was reorganized to accommodate EOS. (The management for building the EOS Platforms was previously under the Space Station but now it was moved to its own Directorate Level position at Goddard.)

The plans for EOS suffered a major blow when, in 1991, funds were allocated such that the Space Station received full funding, while EOS and other projects were frozen at FY 1991 levels—a trend that has continued to the present. Facing a greatly reduced budget ($6B) from what was originally promised over the course of the decade, the EOS Program was *restructured* considerably to make itself more resilient and flexible. Plans for the large EOS-A and EOS-B platforms were recast into six smaller platforms with more focused objectives. Missions that would eventually evolve into Terra, Aqua, and Aura as we know them today were now in place—AM-1, PM-1, and CHEM-1 respectively. There were also plans for a *second series* of missions—i.e., AM-2, PM-2, etc.

In 1992, the decadal budget lost another $3B prompting yet another round of *rescoping*. The idea of a *common spacecraft* for PM-1 (Aqua) and CHEM-1 (Aura) was developed as a cost-saving strategy. The budget cuts continued, and the program was *rebaselined* in 1994, and *reshaped* in 1995. Then in 1997, EOS went through a *biennial review* to consider the implementation strategy for the program and better align it

[1] In the June 1989 (*Volume 1, Number 3*) issue of *The Earth Observer*, the late Renny Greenstone compiled *A Condensed History of the Earth Observing System* that gives a nice summary of the origins of the EOS Program.

with the other parts of what had become known as the Earth Science Enterprise. (Details of these revisions and reviews have been reported on in detail in other locations.[2])

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[2] The *1995 Reference Handbook*, pp. 14-23, and the *1999 EOS Reference Handbook*, pp. 15-19 reported extensively on these revisions to and reviews of EOS, their purpose, guiding principles, and outcome.

## *The Names Have Changed… but EOS Remains*

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***Did you know??*** The EOS Program was originally part of NASA's Mission to Planet Earth, which later became The Earth Science Enterprise, and is now part of the Science Mission Directorate?

EOS was originally part of a larger NASA program called *Mission to Planet Earth.* The title MTPE originated in 1988 in a report on future directions for the U.S. civil space program by a commission led by former astronaut, Sally Ride. The name took hold after the 1990 *Report of the Advisory Committee on the Future of the U.S. Space Program* talked at length about the idea of NASA studying Earth in the same way it does other planets. In 1993, The Office of Mission to Planet Earth (MTPE) "Code Y" was created at NASA HQ. **Shelby Tilford** was the first Acting Associate Administrator for MTPE, **William Townsend** served as Deputy Associate Administrator (AA), **Michael Luther** led the Flight Systems Division, **Dixon Butler** led the Data and Information Division, and **Robert Watson** led the Science Division. In 1994, **Charles Kennel** replaced Shelby Tilford as Associate Administrator for Mission to Planet Earth, and served until late 1995, when **William Townsend** took over as Acting AA.

In 1998, MTPE was renamed the *Earth Science Enterprise* to align it with NASA's other areas. **Ghassem Asrar** became Associate Administrator for Earth Science. In 2004, NASA was again transformed to align itself with President Bush's *Vision for Space Exploration* that involved a concentrated effort to return human beings to the Moon and eventually continue on to Mars, and the Enterprises were reorganized into Missions. Earth Science (which includes EOS) originally fell under the Sun-Earth Division, but the two were later separated. Earth Science is now one of four divisions under NASA's Science Mission Directorate (SMD), and **Michael Freilich** serves as Director of the Earth Sciences Division of SMD.

## *The Evolution of Our Logo*

***Did you know??*** The masthead or logo for *The Earth Observer* has evolved over the years—the graphic on page 5 shows how the logo has changed over time.

When our publication first began in 1989, JPL and Goddard shared management of EOS. The original logo shows a crescent of our home planet. The original idea was that the logo would evolve over time and more of the Earth would be revealed as the EOS program progressed.

However, shortly thereafter, a Non-Advocate Review of the proposed EOS program took place and one recommendation was to consolidate EOS project management at Goddard. To mark that change, the logo for *The Earth Observer* changed so that "temporary" logo only lasted for a few months. In 1990, The General Electric Astro Division (Princeton, NJ) designed a program logo that was adopted for *The Earth Observer* and was used, with slight variations, until 2004. After that time, new communications guidelines required us to remove the program logo from the front and replace it with the NASA agency logo. ■

# In Memoriam

**Reynold "Renny" Greenstone**
*September 30, 1924 - February 7, 2008*

On February 7, 2008, our esteemed colleague, Renny Greenstone, passed away at his home in Brookeville, MD, from complications of cancer. Greenstone was a meteorologist, physicist, technical writer, and editor. He joined the Earth Observing System Project Science Office (EOSPSO) in 1990 after having been involved in the early plans for NASA's Earth Observing System. He was a valuable asset to the EOSPSO team with his vast knowledge of the program and his technical writing and editing expertise.

Greenstone was born in Far Rockaway, Long Island, NY, and served with the Army Air Corps meteorological program in the Pacific theater as a weather forecaster during World War II, flying weather reconnaissance on bombers. He also served in the Marshall Islands during the Bikini atomic bomb tests.

After World II, he studied meteorology at New York University, received a master's degree in physics from the University of Maryland, and did postgraduate work toward a doctorate in meteorology.

He enjoyed travel, enjoyed monitoring classes, and took Italian for several years in an effort to learn the language for his travels to Italy.

Greenstone was a valuable asset to his community as well, as an active volunteer in theater both as an amateur actor and an audience participant; he described plays in real time via a closed-circuit radio system for the visually impaired theatergoers. He was an avid race-walker for many years, and participated in the Komen Race for the Cure and the Relay for Life.

Greenstone will be greatly missed by his scientific colleagues as well as his community. It is perhaps fitting that *The Earth Observer* should pay tribute to him in the same issue where we celebrate our publication's 20th year. Greenstone was a frequent contributor to the newsletter from the very beginning and continued to serve as a technical editor until very recently.

Greenstone is survived by his wife, Carolyn; five children, Todd Greenstone, Brookeville, MD; Holly Kalnoske, Annapolis, MD; Jay Greenstone, Jonesville, VA; Jon Greenstone, Emmitsburg, MD; and Heather Greenstone, Rockville, MD; two sisters; five grandchildren; and three great-grandchildren. Our heartfelt sympathy goes out to his family.

(**Acknowledgement**: much of the information for this article was obtained from The Washington Post.)

# Christmas Among Crevasses: How a Goddard Scientist Spent His Holiday Season

*Robert Bindschadler, NASA Goddard Space Flight Center, Robert.A.Bindschadler@nasa.gov*

*Robert Bindschadler is Chief Scientist of NASA's Hydrospheric and Biospheric Sciences Laboratory, a Senior Fellow of the Goddard Space Flight Center, a Fellow of the American Geophysical Union and a past President of the International Glaciological Society. He maintains an active interest in the dynamics of glaciers and ice sheets, primarily on Earth, investigating how remote sensing can be used to improve our understanding of the role of ice in the Earth's climate.*

*As the leader of 15 Antarctic field expeditions he has extensive first-hand knowledge of the hazards and challenges of working in the Antarctic environment. Other research has taken him to Greenland and various glaciers throughout the world. During his 28 years at Goddard, he has developed numerous unique applications of remote sensing data for glaciological research including measuring ice velocity and elevation using both visible and radar imagery, monitoring new snowfall on the ice sheet by microwave emissions, and detecting changes in ice-sheet volume by repeat space-borne radar altimetry.*

*He has testified before Congress and briefed the U.S. Vice President on the issue of ice-sheet stability and served on many scientific commissions and study groups as an expert in glaciology and remote sensing of ice. He has published over 150 scientific papers, numerous review articles and has appeared on television, radio and is often quoted in print media commenting on glaciological impacts of the climate on the world's ice sheets and glaciers.*

*Following are excerpts from his blog during a recent Antarctic trip. It was first published on Discovery earthlive and is reprinted with their permission. For the complete blog go to* ***blogs.discovery.com/discovery_earth_live/***

***Greenbelt, Maryland, December 7, 2007 3:30pm***

Posted December 13, 2007

**Christmas Among Crevasses**

Every trip needs a theme…[and Christmas Among Crevasses is] going to be mine this field season. I like it because it touches on two very important aspects of conducting scientific research: **scientists don't always get to choose the time they work**, and **we have to go to where the action is**, even if it may be a dangerous place. Both are true for me this holiday season and I'm inviting you to come along by following this blog.

Today I packed up what I think I'll need from my office: maps (images actually), laptop computer, a notebook and some work I didn't quite finish yet (there always seems to be too much of that). I said goodbye to lots of friends there and received good wishes from all. It seemed odd to be wishing them a Merry Christmas and Happy New Year, but I won't see them again until 2008.

Why? Because I'm preparing for a field trip to Antarctica. It's my 15th Antarctic field trip. I am leading a new project designed to find out what is causing a major part of the West Antarctic ice sheet to become suddenly so active. Satellite-based observations, supported by some airborne measurements have shown that ice flowing into the Amundsen Sea is thinning rapidly (a few meters per year) and accelerating (a few percent per year). The spatial pattern of change suggests that the cause is warm water melting ice more rapidly underneath the floating fringes of the ice sheet. These floating fringes are called *ice shelves* and are hundreds of meters thick.

Why now and what's the danger? The sun is up only six months of the year in Antarctica and we are aiming at mid-summer because we think we'll have the best chance of good weather then. The danger comes from all the crevasses on this ice shelf. The fast motion of the ice (and I'm talking ripping fast for ice—**10 m/day!**—that's more than **1 ft/hour!**) breaks the ice apart. These crevasses are BIG—tens of meters across and hundreds of meters long. Most are hidden beneath fragile *snow bridges* that can collapse if someone (like me) were to step on one. I don't intend to, but that part of the story will come later.

This weekend it's time to pack the rest of my clothing, say goodbye to wife and cat, and start the journey. By Christmas we hope to be camped on the ice shelf that is fed by the Pine Island Glacier (PIG). We've posted more information about this project on the Pine Island Glacier Ice Shelf Web site *pigiceshelf.nasa.gov*. And I'll let you in on more of the story, too, as the trip unfolds.

***McMurdo Station, Antarctica, December 25, 2007***

Posted December 25, 2007

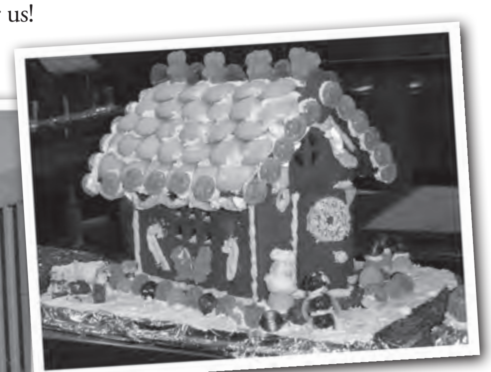
**Santa Gets Around**

A polar "Ho Ho Ho" to you all. Sunday night was the Christmas party in the "Heavy Shop." Most of the town turned out—many in rather bizarre costumes: a Santa on a skidoo; a 10 ft-tall tissue-paper abominable snowman; and reindeer antlers made from exhaust manifolds were but a few examples. Fancy gingerbread houses were on display in the galley. Decorations appeared on many doors and within many offices.

"Merry Christmas" was definitely the greeting most often given today, and the internet and phone lines were crowded. I called home, too.

I was prepared to be *in the field* on Christmas, but I'm not; nor am I home with family. To be in between leaves me with an odd feeling. Until I get into the field, I cannot make progress toward getting home. It's a funny state of limbo.

My greatest pleasure this season has been singing in the local choir that is composed of volunteers. We had three performances: the Christmas party; a version of Lessons and Carols prior to Midnight Mass at the Chapel; and today (Christmas) in "MacOps," the radio room to broadcast our carols to the field parties. South Pole Station even returned the good cheer by singing some carols for us!



Christmas at McMurdo: A tree made from a tent, a gingerbread house, singers singing carols, and a rather motley looking crew of Santas.

*McMurdo Station, Antarctica, December 27, 2007*

Posted December 30, 2007

**Hanging in McMurdo**

I haven't been doing much the past two days. This situation reminds me of a primary requirement of Antarctic field work—*patience*. Usually what demands patience is the infamous Antarctic weather. The concept of *wind chill* is very familiar, but few may know that Paul Siple, at 19 and an Eagle Scout with 60 merit badges at the time, began his illustrious Antarctic career in 1928 by being selected from 800,000 Boy Scouts to accompany Admiral Byrd to Antarctica. Years later he formalized the concept of wind chill and even the term itself with seminal measurements during an Antarctic season recording freezing times of water at various temperatures and wind speeds.

It's an effect you quickly adjust to down here. **If you want to know how many layers of clothes to put on before leaving your tent, listen to the wind and don't worry so much about the temperature.** On a grander scale, wind moves a lot of snow around here. What ultimately stops some of the snow is being jammed into the icy surface of a snow dune, called *sastrugi* (after the Russian for *snow dunes*).

Another thing that blowing snow can stop is field work. Snow moving in the air above the surface, can keep you in your tent for days. It finds its way into your clothes through even the smallest openings, where it melts and threatens to get you wet and COLD. Driven against your skin, it can feel as sharp as sand in a sand storm.

The best remedy for these conditions is patience. Eventually, *even I* will fly out of here, deeper into Antarctica, where the mysteries of sudden and dramatic ice sheet movements wait to be solved. Watch out PIG, I'm still coming!!

Until then, I wait.

McMurdo Station is a bustling little town of about 1,200 people during the summer. Part way-station, part frozen metropolis, it boasts a hard-working population of energetic specialists.

*McMurdo Station, Antarctica, December 31, 2007*

Posted December 31, 2007

**Plan C and then D**

I'm anything but ungrateful. The efforts to get a few of the last field projects into the field are admirable. A lot of good ideas have been tossed onto the table both here and at the deep field camp, called West Antarctic Ice Sheet (WAIS)-Divide, where we eventually must go before our final destination.

But as last week finished, the decision to scout out a possible deep-field landing site for the large LC-130 *Hercules* aircraft to cache our cargo near the ice shelf had been scrapped. In its place was a new plan to use the *Herc* to air-drop fuel so that the smaller *Twin Otter* could refuel and thereby move us and our material in small bits the 300 nautical miles between WAIS-Divide and the PIG ice shelf. WAIS Divide is at 79.4 S, 111.2 W and eventually our PIG Shelf camp will be at 75.1 S, 100.1 W. You can go to *Google Earth* to plot these positions and see how far we still have to go.

But back to planning.

There were concerns about the environmental risk of air-dropping approximately 50 fuel drums and whether there were enough parachutes and netting to complete the mission. Fuel drops are subdivided into palettes of 4 drums each, with about 16 in of corrugated cardboard beneath, to absorb the shock of impact, a parachute to slow descent, and secured with heavy webbed netting, to hold everything together.

By this morning, it looked as though an air-drop was possible later this week. That's when Plan D was spawned. Now maybe I'm out of date in the time it has taken me to write this blog, but what I heard this morning was that a second *Twin Otter* was heading for WAIS-Divide today so they could start deploying the two field camps even before the fuel drop, so they will have to either stage some fuel themselves or take some along. Either way, they will not be able to haul as much of our camp and science cargo as quickly, but will be able to start right away.

If weather doesn't disrupt Plan D (leading to Plan E), then our group will pack our socks and undies tonight to leave McMurdo tomorrow, arriving at WAIS-Divide sometime tomorrow evening.

***WAIS Divide, Antarctica, January 2, 2008***

Posted January 2 2008

**On Top of West Antarctica**

Yesterday came the call we've wanted since arriving in McMurdo. We were manifested to fly to the WAIS-Divide camp in West Antarctica, our jumping off point for the PIG Shelf and a 1000-mile step in the right direction. Check-in time was 9:00 a.m. for a 10:00 a.m. departure. We eagerly packed and came prepared to get weighed the evening before the flight. We didn't break the scale, so I guess we haven't been overeating too much.

Not long after 10:30 a.m., we were strapped in and heading down the runway. Then we slowed, turned and headed down the runway again. Then we slowed again and headed down the runway even faster. This back-and-forth continued for 10 takeoff runs before we finally were able to get airborne. I'm not sure what the problem was, but we all were glad to be in the air.

Three and one-half noisy hours later, we descended to the snow strip and made a smooth landing at WAIS-Divide where a 3500-meter long ice core is being drilled to recover valuable paleoclimatic records. Tomorrow they take their first "real science" core. Everyone is excited.

We're excited, too. The weather forecast is for gradual improvement. Before dinner we located all 9,000 lbs of our cargo. We'll talk to the *Twin Otter* pilots tomorrow and begin to separate our gear into individual flight loads of about 1900 lbs each. By the time we're done, we will have lifted every pound of the 9,000 a couple of times. I'm getting tired just thinking of it. It's been a long day. I'll try to send a blog tomorrow, but the bandwidth from here is too small to include a picture. Time for bed.

The aerial workhorses of the Antarctic this season: the large LC-130 *Hercules* can haul up to 25,000 lbs and supplies the major stations and large field camps; the *Twin Otter* does the precision work and is going to get us onto the PIG ice shelf carrying 2000-lbs loads.

***PIG Shelf, Antarctica, January 3, 2008***

Posted January 3, 2008

**Success!!**

On the ice shelf at last!! We made it to a place no one has ever been, a place many colleagues thought we could never land, a place where we believe drastic changes in the ice sheet are being triggered, a place I have been dreaming of getting to through more than two years of planning.

Whoa, my feet didn't sink into snow at all. The surface was really, really hard. That's why the landing had been a little rough. It will make for safer travel. Bridges across crevasses will be firmer, able to hold more weight. But my excitement is getting me ahead of the story.

Our reconnaissance flight was tacked onto the end of the final put-in flight for the group studying the neighboring Thwaites Glacier. After that, we had to add fuel from palettes of fuel drums the Air National Guard had parachuted to the surface just the day before. Our mission was still 100 nautical mi away.

That final leg of our journey became very scenic as we neared the PIG ice shelf. A multitude of crevasse fields beneath us told of rapidly moving ice. We could even see blue water beyond the shore peppered with thin sea ice and a few larger, thick tabular icebergs. This is a very active place where the ice sheet races to the Antarctic coast and reenters the world's ocean.


A palette being prepared for air-drop. Imagine the pile of boxes replaced with 4 drums of fuel, the webbed netting strapped down tightly and a small parachute pack attached to the top and you have what is being prepared for us.

The PIG shelf began to appear on the horizon. First as bright areas of crevasses, miles across. Single crevasses were monsters 50 ft across and sometimes more than a mile long. Holes in snow bridges let us look straight down into the icy voids, often with draperies of snow hanging tens of feet into the blackness.

I began to see features out my window that I recognized from the images I knew so well. And then, there it was!!! The "sweet spot" of the ice shelf. No crevasses! We began a careful aerial reconnaissance that took us back and forth, first at 1500 feet altitude, then 1000 feet, finally a very slow pass at 500 feet. Looking at different angles, every set of eyes in the plane was straining to see even the slightest hint of hidden crevasses.

There were none to be seen so the next step was to "ski drag." This is when the airplane flies along the surface, using its own weight to press downward on the snow, but flying fast enough to remain airborne. The pilot then circled around to look for bridges that may have collapsed along the drag line. There weren't any, but the tracks were so slight, he wanted to repeat the procedure with more pressure. Rough again, but no danger spotted. We circled to land.

This was exciting. There was a lot of emotion mixed with the excitement. A *Twin Otter* can stop very quickly and in less than 400 ft and a couple of seconds, we came to rest on the ice shelf. It WAS possible!

We helped the pilots mark their runway with black garbage bags we filled with snow. With a shovel in hand, I couldn't resist digging a little deeper. I discovered a hard layer of solid ice about an inch below the hard crust. Below that, there were more icy layers with snow the consistency of sugar.

***PIG Shelf, Antarctica, January 3, 2008***

Posted January 5, 2008

**Oh No!**

I couldn't believe my ears. The pilot's voice coming through my headset started with "Bob, we have some bad news"… our landing site was too hard, too rough and too short. This translated into limiting take-off weights. So, although they would be able to get us onto the ice shelf with our camping gear and scientific equipment, it would be very hard to pull us out without taking far too many loads.

They asked what I wanted to do—a hard question to be hit with an hour after the elation of a successful landing. I felt like the entire program we were finally going to be able to do had just been gutted. The second *Twin Otter* supporting us was already full of our first cargo load and was at the ice shelf. They were looking for an alternate spot and having no luck. Could I advise them where to look? No. I only knew of one spot like the one we had just visited. They had seen a nice spot off the ice shelf. Was that OK? No. The whole point was to measure water properties and speed of the ice shelf.

Meetings between me and the pilots and a teleconference with science program managers in McMurdo were already arranged by the time we landed back at WAIS-Divide. A near-immediate redesign of my program was being requested. It was not a pleasant moment.

We had actually landed on the ice shelf. We had finally overcome that long-standing hurdle and I was racing along thinking how great the next week was going to be as we began to actually make measurements….and…it had been snatched away by this unfortunate decision. Before long, I heard from McMurdo the unequivocal decision "you will not land on the ice shelf again this season."

I met with the rest of our field team, presented the situation and we discussed what could be salvaged. So much required us to be on the ice shelf. The only item that could be useful off the ice shelf was the automatic weather station. We examined imagery to find the best candidate locations and are hoping to build and deploy the station at one of these sites starting tomorrow.

Tonight I am an emotional wreck. The range of emotions hit some enormous highs along with some abysmally low lows.

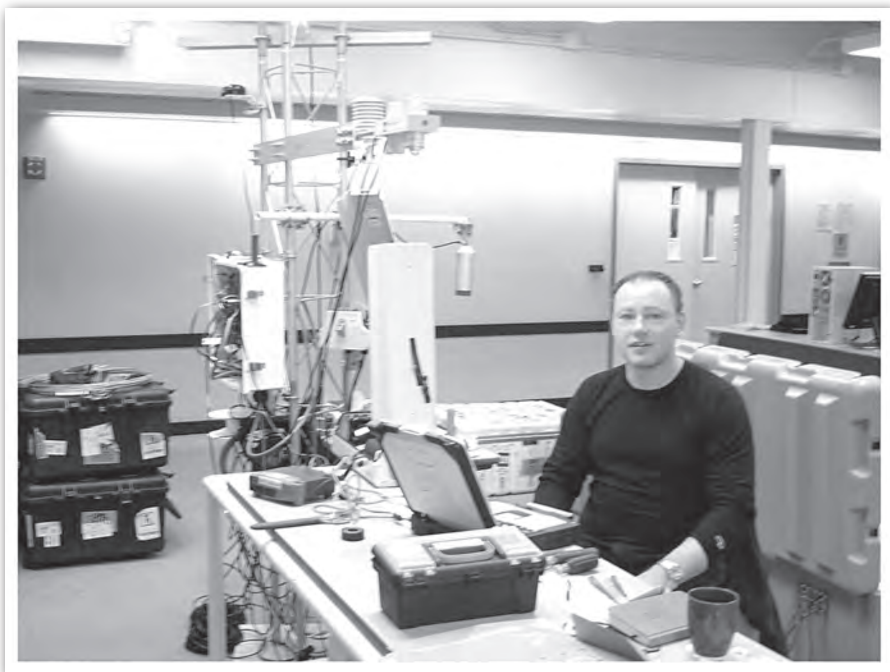
***McMurdo Station, Antarctica, January 11, 2008***

Posted January 11, 2008

**Making the Best of Things**

I'm still smarting from the emotional crash of having actually landed on the ice shelf, only to be told the *Otters* would not land there again (this season). Assuaging the pain is the knowledge that at least now we have a field team deployed to a site adjacent to the ice shelf where the snow is softer, the winds apparently milder and the view spectacular.

The three team members are putting up the automatic weather station. Antarctic research certainly has gone "high-tech." I still remember the days of needing to take *sun shots* to determine our location, navigation was done with compass and distances were measured by steel tape. Hey, that wasn't so long ago (i.e., I'm not THAT old!); I'm talking about 1982, my first Antarctic season.



My colleague **David Holland** testing his "baby," the automatic weather station. He had to set up a compressed version so it fit in the lab, but it all checked out. In the field the tower will be 14 ft tall and be rigged to support winds of at least 150 mph.

Our group is trying out a combination of 10 deep-cycle batteries, two large solar panels and two wind generators, to maintain sufficient power through the winter for our weather station, but others are using it for other instruments like Global Positioning System (GPS) units. Our installation will be particularly useful, because we include two web cams that will take a daily picture that we not only add to the weather information, but will allow us to see if the snow or wind or ice are making life difficult for the instruments and power components.

I stayed back at WAIS-Divide because a fourth person would make our camp heavy enough that an extra flight would have been necessary to get us deployed. I also felt that there were other ways I could be more useful to the project.

What I was able to contribute was a new use for the two winter-over GPS units we have here. They are still just sitting idle on the cargo line and an unused scientific instrument is a terrible thing (at least to a scientist). The PIG ice shelf is fed by the very fast Pine Island Glacier and this glacier has a number of tributaries that feed it. These tributaries flow at speeds that gradually decrease upstream, improving the chances for finding a crevasse-free spot. One tributary lies within 20 mi of the weather station site and the next closest is only 40 mi farther. My plan is to be flown upstream along these tributaries from their junctions with the main flow of the glacier, where crevasses are rampant, until a crevasse-free area allows the Otter to try a landing. If it can land, I will be left with the GPS equipment and a lucky WAIS-Divide staff person to set up the instruments while the *Otter* hops over to the weather station camp. There they will pick up those three folks and then return to me. Once we are done, we will all return to WAIS-Divide.

And so it goes. Plans change and change again. Good Antarctic field scientists never accept just giving up and going home without squeezing every possible productive use of the equipment and time we have here.

***McMurdo Station, Antarctica, January 13, 2008***

Posted January 13, 2008

**CNX**

There is a white, dry-erase board just inside the galley door where the current information on flights is posted. Each evening, McMurdo usually passes out the flight schedule for the following day. A flight to WAIS usually is included, but early the next morning the dreaded "CNX" is added to the board. That's the code for a cancelled flight and it has happened almost daily this past week, both for *Hercs* bringing camp supplies out and returning some people whose work out here is done, and for *Twin Otters*, the airplane we still need to deploy our GPS stations. First our weather was poor, then McMurdo received a windy, heavy snowfall that shut down the runway there.

The only flight that arrived this week was a *Twin Otter* that had been at the South Pole. We were glad to receive it. The three members of my team were still out at a remote camp waiting to be picked up. Their work installing the automatic weather station was finished a day earlier and it is operating normally. They were far from uncomfortable. While WAIS was being hit with 20-kt winds, drifting snow and wind chills around -30° C, they were in the sunshine with light winds and temperatures near or even ABOVE freezing. They saw their situation differently, however, claiming that because their two bottles of wine were now empty, it was time to be pulled out.

I was able to make dual-use of the pull-out flight by loading the *Otter* at WAIS with the equipment for a GPS station. While that was going on, Ben, my super-strong field hand, and I began setting up the GPS station. It seems silly—the GPS unit itself weighs all of 3 lbs, but the power system required to get the GPS to operate through the long, cold, dark Antarctic winter weighs about 1000 lbs. Most of that is batteries—ten big heavy ones—but the system also includes two solar panels to recharge batteries during the summer, and two wind generators to help the batteries get through the dark winter. Add steel guy lines designed to hold it all together in 150 mph winds, and there is a lot of work to install the system.

I had prefabricated a lot of the pieces to minimize the installation time, but it still took two hours—the final 30 minutes after the *Otter* had returned with the three other happy campers. The pilot was getting very antsy during those final 30 minutes because the report from WAIS was that the weather was getting worse. It improved just enough during our two-hour flight home that we had no trouble landing at WAIS.

That was Thursday. Today is Sunday and nothing of note has happened in between. We had hoped to have that *Otter* for six more hours to install our second, and last, GPS, but it was called back to McMurdo the very next morning. A person here hurt her shoulder and the medic wanted her to get an X-ray as soon as possible. She had already waited four days as "CNX" appeared on the flight board day after day.

The last two days another *Twin Otter* coming from Patriot Hills has been CNX'd. After yesterday's cancellation, I held a small team meeting to see how people felt about calling a halt to our season. Some will return to McMurdo but David and I remain determined to get the second GPS installed at least along a tributary of the PIG. We'll stay here until we are forced to leave. We've come too far not to leave the GPS where we can get some valuable information on ice motion of the glacier. I've had to start adjusting my schedule back home. **Antarctic science rarely runs on schedule.**

***PIG GPS Site, Antarctica, January 13, 2008***

Posted January 13, 2008

**Sweeeeet!**

At Last!! Today was a good field day. A *Twin Otter* was able to make it to WAIS-Divide in the afternoon, took us to our second and final site to deploy a wintering over GPS…a gorgeous blue sky, NO WIND, and just to spice up the spot, monstrously large crevasses nearby. Two of our team were supposed to be heading back to McMurdo this same day, but the flight was cancelled, so all four of us were able to work on this together. The conversation ran pretty free over many topics with a lot of kidding and laughing. We all enjoyed what we were doing, who we were doing it with, and where we were doing it. It was absolutely great!

For all the frustrations of this season, we ended this day with a wonderful sense of accomplishment. The *Twin Otter* crew allowed us the luxury of a few final minutes to get "team pictures" at the site before we left. We didn't return to WAIS camp until midnight, but we were still pumped up and stayed up for another couple of hours feeding our faces and talking about how beautiful the day was.

Having finished this work, we all can now queue up for the next *Herc* for McMurdo. **Each field season, I rediscover the depth of the bond that is generated by the shared experience of working together in an environment that presents a variety of challenges that must be overcome…we will be life-long friends.**

When the season ends, it often ends in a flurry of activity. This may be true again. In anticipation of that *Herc* arriving today (the weather is good now, but forecast to "go down"), we have to get our personal gear together relatively quickly. And once we reach McMurdo, David and I will have to keep hopping to return all our camp equipment, radios, skidoo parts, etc. before showing up for tomorrow's flight off The Ice to New Zealand. Then another quick overnight before the commercial flight home. The transition can be quite jarring.

Part of me wants to sit back and savor our accomplishments. We've responded to the massive disappointment of having landed on the ice shelf only to be told we couldn't return there. We've deployed our instrumentation as close to the ice shelf as is safe considering its bounding crevasse fields, and we will be able to "watch" it in three spots throughout the winter and until we return next year with the data that will be transmitted back from our instruments. We talked about it last night and everyone is proud of how we met the numerous challenges that we faced the past few weeks.

***WAIS-Divide, Antarctica, January 14, 2008***

Posted January 15, 2008

**Fury**

I'm prepared to leave Antarctica now. But today I was reminded that Antarctica makes the rules down here and the fact is that Antarctica is not ready to let go of me yet.

The morning sun was high and shone brightly from a crisp blue sky. Not much to catch up on—I only had some last minute packing to do and for that I was waiting until notified that the *Herc* had actually left McMurdo. It's a common superstition with Antarctic field hands that taking your tent down before the plane is in sight is bad luck.

Much to my surprise, just before lunch, Elizabeth, the camp supervisor came into the galley and announced that *Skier 61* (the name of today's *Herc* mission to WAIS-Divide) was cancelled. Cancelled?! She said the forecast was for increasing winds and decreasing visibility beginning in the next two hours. It's sometimes hard to believe these forecasts; in season's past, they have been wrong at least as often as right. Well maybe the forecast models are getting better because almost on cue, the winds began to build. By 3:30 pm, when the *Herc* had been scheduled to arrive, visibility was "nil/nil," meaning no horizon was visible and there was no surface definition.

When this happens in calm conditions, it is called a *white out*. This time the reason is blowing snow. Snow is blowing through camp in horizontal sheets, nearly hiding all buildings, vehicles and cargo in a thick haze of white. The only sounds are the howling wind and the sharp cracking of the flags on the many bamboo poles that mark where items are located.

Inside, the cook is playing music as he usually does (he has about ten million songs on his laptop) and there are some conversations at the tables, but the outside sounds penetrate the soft walls and occasionally drown out the music. To be sure, the galley is warmer than outside, but the wind sucks heat from everything and even cranking up the stove doesn't prevent the inside temperature from being colder than it has been the past week.

Most of the people in camp are involved in the ice-core drilling project based here and they are still working three shifts a day so they come and go. For those of us just waiting for the *Herc*, many diversions are available—*Cribbage* and *Scrabble* are among the most popular. There are many laptops open and people share their pictures and music. The slapping flags tell us the weather is not changing.

After dinner, Elizabeth shares with us the forecast that winds will intensify, gusting to 40 kts through the night lasting to at least 5 a.m. "Be careful," is her message.

Many people still sleep in tents at the edge of camp. There is usually some object (a flag, tent or building) every 30 ft to prevent people becoming disoriented. Walking outside requires focusing on where you are going and remembering that each step you take is crucial. New drifts can grow quickly. It's not dangerous as long as you remember where you are.

The movie playing in the Rec hut doesn't interest me and I decide to go to bed before 10 p.m. I have to shovel a small drift away to get into the Jamesway hut I'm sleeping in. The stove is working but the interior is still cold. The other door has been blown open and a drift is growing inside the hut. I shovel that snow back outside. The door frame has twisted so the door latch doesn't hold. I shove the fire extinguisher and an unused heater against the door to hold it. I breathe a long sigh of welcome relief as I slide into my sleeping bag and pull it up over my head. I will be very warm soon.

I'm glad that as storms go, this is pretty mild. Storms with winds of 100 kts, even 200 kts are not unusual during winter. I wonder, but not too long, how they must feel and sound as I drift to sleep.

***A Field Season's Final Thoughts***

Posted January 17, 2008

**On the Herc Flying Back to McMurdo Station**

Today the weather cleared at both WAIS-Divide and McMurdo and, much to the delight of people at McMurdo waiting to go to WAIS camp and of people at WAIS waiting to go to McMurdo, a *Herc* managed to make the trip. Coming from

McMurdo were a group of inspectors who needed to check out the construction of the ice coring facility, a few replacement camp people, and Charlie Bentley, a much renowned glaciologist whose first season in West Antarctica was 50, that's right 50, years ago during the International Geophysical Year. Going to McMurdo were our group and a few others who had been stranded at WAIS many days longer than we.

This flight marks the end of my field season. We have a few tasks to do in McMurdo: returning keys and equipment to various suppliers, etc., however, the steps are very routine. If I complete them quickly enough, I will be able to get a seat on the flight to Christchurch, New Zealand tomorrow evening. It's a flight I'm GOING to make. If airline connections are good, I should be home to see my wife about 30 hrs after leaving Antarctica.

I leave you with a final picture of me standing on the PIG ice shelf. This was one of our objectives we met. Unfortunately, we were not able to set up our camp there, but we placed our instruments in valuable locations and have learned a great deal about the area that will feed directly into our planning for next season's work.

**Robert Bindschadler** standing on the Pine Island Glacier ice shelf with the *Twin Otter* aircraft that landed there in the background. This remains the only landing ever on this ice shelf and confirmed that an uncrevassed area large enough for a safe landing was possible.

I've written about the challenges we've faced (and overcome), the frustrations of weather and logistics, and the science we've done (and why). **What my mind turns to now is the privilege I feel to have the opportunity to work here.** I can't think of a better place to do Earth science research. Each season I have engaged in has instilled in me a sense of wonder for the natural world, an appreciation for the opportunity to work here and undying gratitude for the many, many people who work to make my research possible.

Antarctica is a magnificent continent. Its majestic beauty is beyond description, its scale is unimaginable, and its intensity like no other place I've been. I've flown for miles and miles over seemingly unending emptiness, but I know that beneath me lay dynamic features so huge that the eye cannot take them in..

**Nature speaks more loudly in Antarctica than anywhere else I've experienced.** Her storms force humans to submit to her weather. You come to be grateful for the windows of milder weather when you can do your research because when she roars, you must wait. She rules—and we are, and will probably always be, only visitors.

I work in a relatively small field of research. There are maybe two dozen people in the U.S. and maybe three times that worldwide who do the type of work that I do—

and half of them don't include field work in their research portfolio. It is rewarding research for many reasons. I can think of nothing so exciting about science as making new discoveries. The new urgency of my research brought by the rapid acceleration of changes we observe adds pressure, but also an increased sense of importance to what I'm doing in Antarctica.

Finally, there is a very strong sense of gratitude for all the support that surrounds field science like mine. From the field camp workers who will do whatever you ask of them, to the McMurdo support of 1000 plus, to the citizens that support the work with their tax dollars, I never leave the field without being reminded that I do not work alone.

From here, I return to my office and laboratory, to begin analyzing the data from this season and planning the next season's work. David Holland and I will meet with our other co-investigators at the end of February. Not long after that, I will be discussing with the National Science Foundation the field support we will need for the next season. If DiscoveryEarthLive wishes, I will continue to report on our progress.

Until we "meet" again. ■

# KUDOS

**EOS Scientists Chosen as 2008 AGU Fellows**

Each year, the American Geophysical Union (AGU) recognizes individuals who have made outstanding contributions to the advancement of the geophysical sciences, to the service of the community, and to the public's understanding. The following members of the Earth Observing System scientific community have the distinction of being named Fellows for 2008. Not more than 0.1% of AGU members are given this honor each year.

**Robert Bidigare**, University of Hawaii
**David Chapman**, University of Utah
**Dudley Chelton, Jr.**, Oregon State University
**Elfaith Eltahir**, MIT, Cambridge
**Jeffrey Kiehl**, National Center for Atmospheric Research, Boulder
**James Kirchner**, University of California, Berkeley
**Charles McClain**, NASA Goddard Space Flight Center
**Michael McCormick**, Hampton University, Hampton
**Robert Nerem**, University of Colorado, Boulder
**Venkatachalam Ramaswamy**, NOAA GFDL, Princeton University
**John Rundle**, University of California, Davis
**Jagadish Shukla**, George Mason University

*The Earth Observer* staff on behalf of the entire scientific community congratulates these individuals on this outstanding accomplishment.

# Getting at Groundwater with Gravity

*Gloria Hicks, National Snow and Ice Data Center, Library@nsidc.org*

*This article originally appeared in the* ***2007 Distributed Active Archive Center (DAAC) Annual. The Earth Observer*** *has obtained permission to reprint the article. The original story, including color graphics, appears at:* ***nasadaacs.eos.nasa.gov/articles/2007/2007_gravity.html.***

**Introduction**

In southwestern Nebraska, a boom fueled by groundwater is going bust. In the 1970s, new irrigation technology made it possible to grow corn, which is much more lucrative than dryland wheat, in this sandy region. Farmers moved in, drilled wells, and planted new cornfields. But by the late 1970s, groundwater levels had already begun to fall. Thirty years later, towns shrivel as farms decline and families leave for greener pastures.

"Around the world, the availability of groundwater has actually affected the economic success or failure of a region," said **Sean Swenson**, a researcher in the Advanced Study Program at the National Center for Atmospheric Research (NCAR). "According to the United States Geologic Survey (USGS), 50% of people's fresh water comes from the groundwater found in wells. In rural areas, that rises to 90%." **Whether for personal or commercial use, humans heavily depend upon the availability of groundwater.**

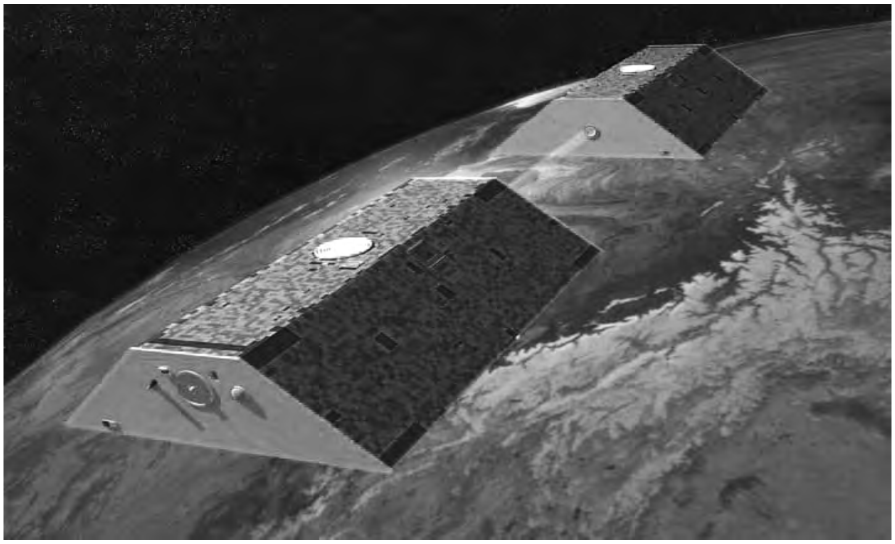
With so much depending upon fresh water, local and national officials have long recognized the need for measuring groundwater resources; in some areas, they have established a systematic groundwater observation program. Yet groundwater resources sprawl across huge sections of land, crossing community and political boundaries and making it hard to understand how much water actually flows under any given tract of land. To better understand this essential resource, researchers have developed an innovative model to assess the amount of groundwater available over large areas. This model uses data from instruments on a new pair of satellites that measures changes in the Earth's gravity.

**A Renewable Resource in Danger**

In May 2006, Colorado State Engineer Hal Simpson ordered the shutdown of 400 wells in Platte County, CO, to ensure water for contracts downstream. As a result, the Colorado farmers who relied on these wells for their crops were out of business for the year.

"In some places, it's unclear how much groundwater exists, and it's unclear how fast it's going to run out," Swenson said. "You get a certain amount of recharge every year, and if you exceed that, eventually you're going to use up all of your resource. It will be gone."

Irrigation allows farmers to grow water-thirsty corn on the relatively arid plains of the western and midwestern United States. But overuse of groundwater supplies can quickly deplete sources like the Ogallala aquifer, which underlies much of the Great Plains. **Credit:** U.S. Department of Agriculture.



An artist's rendition of the Gravity Recovery and Climate Experiment (GRACE) satellites. GRACE uses two satellites flying in a tandem orbit. By measuring changes in the distance between the lead satellite and the trailing satellite, scientists can determine changes in the Earth's gravity. **Credit:** NASA/JPL-Caltech.

Despite the estimated 3.8 million mi$^3$ (16 million km$^3$) of groundwater flowing under the Earth's surface, wells and springs often fail to provide enough water when and where it is needed. On a national level, the USGS assesses the nation's water supply, but determining if the regional water supply matches the regional need challenges local, state, and national agencies. **Bill Alley**, head of the USGS Office of Ground Water, said, "For certain aquifers, we have a pretty good program underway to track what is happening in that system, but there are other regions where we have very little consistent information over a period of time."

**Searching for Water from Space**

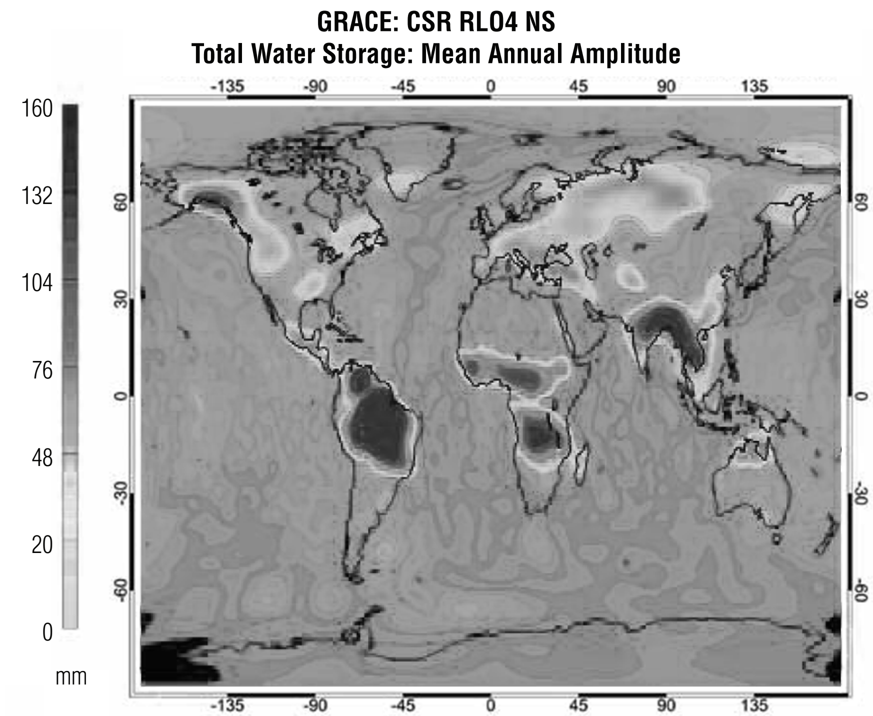
Part of the reason that groundwater monitoring is difficult on a regional scale has to do with measurement methods. Swenson said, "The traditional way to measure groundwater is to dig a well and monitor the water-table level in the well, but a well's water level doesn't translate exactly to groundwater storage. You need to know the properties of the soil subsurface and the aquifer composition to actually determine that." These aspects of the groundwater system help determine the amount of groundwater that an area will typically store. "Basically, different aquifers store different amounts of water," he said.

Until recently, water resource agencies and scientists used only the data gathered by traditional methods to develop water usage models or to determine actual local usage. But starting in 2002, that changed. NASA and the German Research Institute for Aviation and Space Flight [Deutsche Forschungsanstalt für Luft und Raumfahrt] launched two new satellites, flying on the same track about 137 mi (220 km) apart and 310 mi (500 km) above the Earth. This mission, called the Gravity Recovery and Climate Experiment (GRACE), measures changes in the Earth's gravity.

But how do gravitational differences tell scientists about the presence of groundwater? If the Earth were a perfectly round sphere, any point on the planet's surface would have the same average gravity field. However, mountains, deep oceanic trenches, and other features cause minute changes in Earth's gravity. **Just as these mountains and deep trenches change the Earth's gravity field, so do changes in the amount of groundwater.** A satellite's orbit above Earth is partly determined by gravity. So, slight changes in the distance between the twin GRACE satellites as they pass over Earth's features indicate changes in Earth's gravitational field. Scientists can then track differences in the Earth's gravity field from data retrieved from the GRACE satellites, improving their understanding of how water is moving and cycling around the planet.

Scientists like Swenson download and analyze GRACE data from the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) to measure groundwater globally over large areas. Swenson calculated the groundwater levels by analyzing the GRACE data and using models to estimate and subtract soil moisture levels. Swenson said, "The GRACE data provide a broad-scale picture of groundwater supplies, which complements local well measurements."

During the last two years, Swenson has repeatedly confirmed that satellites can provide a method to measure groundwater over entire regions. The success of this approach could help speed the development of a national monitoring system. By combining ground and space observations, the USGS and other national agencies can obtain a more comprehensive picture of groundwater availability across the United States. With this larger picture, the USGS, state, and local decision-makers could work together to conserve shrinking groundwater. "Ultimately, researchers want to see the data being applied in some way. We want it to be useful to people who make decisions," said Swenson.




**Water Storage Data**: NASA's twin Gravity Recovery and Climate Experiment (GRACE) satellites can detect groundwater by measuring subtle variations in Earth's gravity. This image shows the world's average annual cycle of water storage on land, computed from four years of GRACE gravity data. Shades of grey indicate how much groundwater comes and goes each year in various regions; dark shades indicate high levels of annual fluctuation, grading to lighter shades which represent lower levels of fluctuation. **Credit:** Sean Swenson.

**National Groundwater: The Endgame**

At the USGS Office of Ground Water, Alley continues to develop an agenda for a national network of systematic monitoring. However, he has found a number of obstacles in the way of a national program. He said, "Installing wells for monitoring is very expensive and existing wells are limited, which makes the development of a good program tough. **Satellite monitoring of changes in groundwater storage over large regions is a promising supplement to land-based monitoring methods.**"

Still another challenge for Alley exists in the very nature of groundwater. "The amount of groundwater in storage fluctuates between recharging and discharging periods. The GRACE data provide a new way to achieve precise estimates of seasonal and interannual variations in groundwater storage over large river basins or aquifers worldwide, estimates that have not been previously available," he said.

Despite the challenges, Alley believes that regional officials and scientific researchers remain tuned in to the need to measure the essential resource that groundwater provides. "We need to understand the impact we're having on groundwater from pumping and land-use activities and how that is playing out over time," Alley said. "With this information, we will be able to better manage the resource."

People have long depended on groundwater for drinking water, farming, and commercial uses. When groundwater dries up, so can the communities that depend on it. Windmills scattered across the Great Plains mark where people have brought groundwater to the surface. **Credit:** Gary Boyd.

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**Related Links**

NASA Physical Oceanography DAAC: *podaac-www.jpl.nasa.gov/*
Gravity Recovery and Climate Experiment (GRACE): *www.csr.utexas.edu/grace/*
National Ground Water Association: *www.ngwa.org/*
United States Geological Survey Ground Water Information: *water.usgs.gov/ogw/*
United States Geological Survey Office of Ground Water: *water.usgs.gov/ogw/bgas/mission.html*

feature articles

# Urban Growth and Its Impact on Local Precipitation

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*Scientists have long known about the* ***urban heat island effect****, in which cities raise local temperatures, but the effect of urbanization on local rainfall is uncertain.*

The expansion of urban areas has been and will continue to be one of the biggest human impacts on the terrestrial environment. Scientists have long known about the *urban heat island effect* in which cities raise local temperatures, but the effect of urbanization on local rainfall is uncertain. Using a unique combination of satellite images, ground-based weather measurements, and statistical techniques, we find that the rapid growth of cities in South China—see **Figure 1**—reduces rainfall in the immediate vicinity during the dry season. This so called *urban precipitation deficit* implies that local and regional climate will change as the world's population and landscape become increasingly urban. Current estimates are that more than 60% of the world's population will live in cities by 2030.

Our analysis was published in the American Meteorological Society's *Journal of Climate* [*May 15, 2007*, **20**:2299-2306]; the reader is referred here for a more complete treatment of this topic. We used what we consider to be a unique approach that combines analysis of annual Landsat images of the Pearl River Delta in China with the statistical techniques originally developed by Sir Clive Granger, recipient of the 2003 Nobel Prize in economics.

Our first step was to use Landsat images to develop annual estimates of urban extent for each year from 1988 to 1996. During that period, the amount of urban land more than quadrupled—see **Figure 2**.

Now that the satellite data has informed us where urbanization is occurring, we can begin to quantify it and track the relationship between urbanization and rainfall. We studied the development that has occurred around 16 meteorological stations in the area—see **Figure 3**. Around each station, we established three circular buffers, with radii of 3 km, 10 km, and 20 km. Within each buffer, we tracked the *annual fraction* that is urbanized. To investigate the possible effect of the city's shape, we also calculated two spatial metrics: *urban edge density*, which measures the total edge of the urban area relative to the total landscape; and *landscape shape index*, which measures the perimeter-to-area ratio for all urban areas within the buffer.

**Figure 1:** Prior to the economic reforms of the early 1980s, most of the Pearl River Delta in China was covered by agriculture (shown on the far side of the river). Agriculture provided moisture to the overlying atmosphere via transpiration of the crops and evaporation from the soil, irrigation canals, and paddies. Urbanization on the near side of the river transformed the landscape thereby reducing both transpiration and evaporation and speeding runoff. The urban structures also changed surface properties such as roughness and albedo.

1988 2001

**Figure 2:** This pair of Landsat images shows how much the landscape of Shenzhen, China has changed over time. The left image shows a portion of Shenzhen in 1988. (Urban areas appear light grey in the image.) The right image shows that, by 2001, these urban areas have grown significantly.

These annual measures of urbanization, along with time, temperature, and average temperature and precipitation at the other 15 meteorological stations are used as explanatory variables. These variables are used in statistical equations to predict the amount of rainfall at the meteorological station in the center of the buffer. By including temperature, we account for a possible link between the urban heat island and the effect of urbanization on precipitation. By including average values from the other 15 stations, we account for the large-scale effects of especially wet, dry, warm, or cool years.

Previous efforts to look at the relationship between urbanization and precipitation (and temperature) have been hampered by the inability to distinguish between *causation* and *correlation*. If one variable (e.g., urban growth) is found to occur at the same time as another one (e.g., precipitation) we can use statistical tests to determine the degree to which the two variables are related and change together—called *correlation*. However, just because two variables are *correlated* does not automatically mean there is *causation*—i.e., just because urban growth and changes in precipitation appear related and change together, we can't automatically say that urban growth *caused* precipitation to decrease. We have to do more investigation to evaluate *causality*. Most statistical techniques can tell you if two variables are *correlated*, but they don't help much in making the leap from correlation to *causality*.

To help us make the leap from *correlation* to *causality*, we turn to the notion of *Granger causality*. Originally developed by Clive Granger in the 1960s and used in the field of economics, *Granger causality* is a technique that can determine whether a time series of one variable is useful in forecasting another.

*Granger causality* does not guarantee *true causality*, but it is more conclusive evidence than *correlation*. Statistical tests for *Granger causality* are based on the notion of *predictability*—i.e., can we show that if we observe urban growth we will see a change in precipitation at some later point beyond that which is predicted by looking at current and previous values of precipitation and temperature? So the question we need to answer in our analysis is: **Does urban growth *Granger cause* changes in precipitation?** To answer, we evaluate whether our prediction of **current rainfall improves when we include previous values of urbanization in our statistical analysis over what it would be if we based the prediction only on previous values of temperature and precipitation alone.**

As another means of assessing the *predictive power* of urbanization, we evaluated the ability of the urbanization variable to increase the accuracy of predictions for observations that are not used to estimate the statistical equation—a so-called *out-of-sample forecast*.

To do so, we estimate rainfall using two different statistical equations: one equation includes the previous value of the urbanization as a predictor variable and the other does not. Both equations are estimated with data from 15 meteorological stations and used to predict rainfall in the 16th station. (This process is repeated 16 times so there are predicted values for all 16 stations.) **If the equation that includes the previous values of urbanization as a predictor generates a more accurate (as determined by statistical tests) *out-of-sample* forecast for rainfall than the equation without urbanization, then we have another indicator that urbanization *Granger causes* precipitation.**

Our research findings indicate that **the effect of urban expansion on precipitation varies by season and area.** Urban growth **reduces precipitation during winter**, which is the dry season in Southern China. During the dry season, precipitation is more easily affected by local conditions, possibly through changes in land surface properties (e.g. vegetation cover, roughness, or albedo), or increased anthropogenic aerosols. For example, replacing trees with asphalt reduces the amount of water stored near the surface and reduces the amount of water put into the atmosphere. Alternatively, water management caused by human actions associated with urban areas speeds run-off and therefore reduces water supply to the atmosphere. Lastly, high rates of urban energy use increase atmospheric aerosols, which may depress rainfall.

On the other hand, urban growth **has no apparent effect on rainfall during the rest of the year**. It's quite possible that more dominant large-scale atmospheric features such as the East Asian Monsoon mask any changes that urbanization causes during spring, summer, and fall.

The **size of the urban area** also influences the effect of urban expansion on precipitation. The causal relationship between urbanization and precipitation is present around weather stations when urbanization is measured within a radius of 10 km and 20 km, but there is no effect when the measure of urbanization is restricted to 3 km. This implies that new city development must reach a size of hundreds of square kilometers before it will affect local precipitation. (Most large cities cover thousands of square kilometers.)

Finally, the **shape of the city**—as measured by the spatial metrics—does not seem to play a significant role in the urban precipitation deficit. The presence or absence of a causal relationship between urbanization and precipitation is not affected if the fraction of area urbanized is replaced with either *urban edge density* or *landscape shape index*. ■

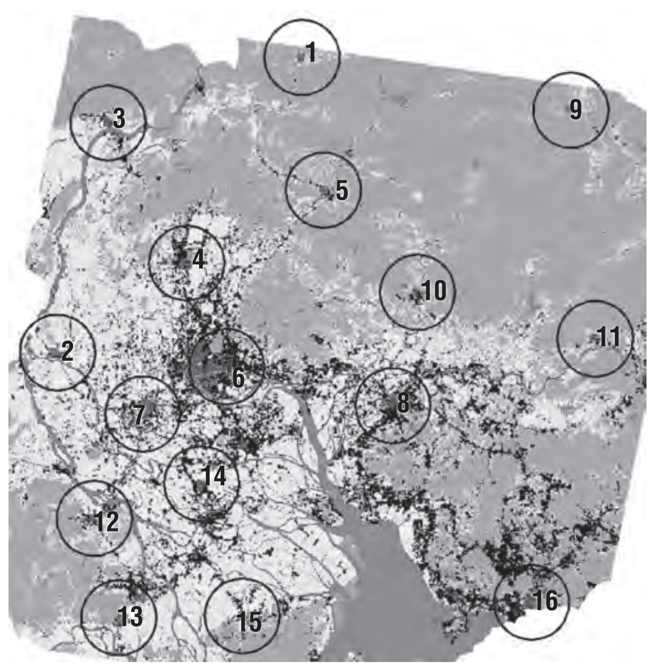


**Figure 3:** This figure shows the locations of the 16 meteorological stations analyzed and the 10-km buffers around them. Urban areas are shown in darkest pixels. Meteorological stations include: (1) Fogang; (2) Sanshui; (3) Qingyuan; (4) Huadu; (5) Conghua; (6) Guangzhou; (7) Nanhai; (8) Dongguan; (9) Longmen; (10) Zengchen; (11) Boluo; (12) Heshan; (13) Xinhui; (14) Shunde; (15) Zongshan; and (16) Shenzhen.

# KUDOS

**EOS Scientists Receive Awards from AMS**

The American Meteorological Society (AMS) named the following EOS colleagues as award winners at their annual meeting in New Orleans, LA in January:

**Gerald R. North**, [Texas A&M University] received *The Jule G. Charney Award*, "For groundbreaking research on climate models, atmospheric statistics, and satellite mission development."

**Raymond A. Shaw**, [Pennsylvania State University] received *The Henry G. Houghton Award*, "For fundamental advances in understanding ice nucleation and the role of turbulence on cloud droplet growth using theory and innovative observational methods.

**David W. J. Thompson**, [Colorado State University] received *The Clarence Leroy Meisinger Award*, "For insightful analysis of the atmospheric circulation variability of importance to climate and weather."

**Robert D. Bornstein**, [San Jose State University] received *The Helmut E. Landsberg Award*, "For over three decades of international leadership in the field or urban meteorology, including fundamental contributions in the areas of air pollution meteorology, urban heat island dynamics, and mesoscale modeling of urban areas."

**Norman G. Loeb**, [NASA Langley Research Center] received *The Journal of Atmospheric and Oceanic Technology Editor's Award*, "For numerous outstanding and helpful reviews, delivered on time, that greatly assisted the JTECH editors."

**David H. Rind**, [NASA Goddard Institute for Space Studies] received *The Bernhard Haurwitz Memorial Lecturer for 2008*, "For outstanding contributions to many areas of climate dynamics and change including development of climate models, understanding of the hydrologic cycle, stratospheric change, paleoclimates, and the role of the Sun.

**David P. Lettenmaier**, [University of Washington] received *The Robert E. Horton Lecturer in Hydrology for 2008*, "For his contributions to the development of macroscale hydrologic models and his studies of the hydrologic impacts of climate change."

**William D. Neff**, [NOAA/Environmental Research Laboratory] received *The Walter Orr Roberts Lecturer In Interdisciplinary Sciences for 2008*, "For scientific and programmatic contributions crossing the boundaries of weather, climate, air quality meteorology and remote sensing, and for the influence these have had on public policy affecting air quality."

**T. N. Krishnamurti**, [Florida State University] was elected an Honorary Member

In addition, the following individuals were elected **AMS Fellows** in 2008:

**Anna P. Barros**, Pennsylvania State University
**Shepard A. Clough**, Atmospheric & Environmental Research, Inc.
**Peter Hildebrand**, NASA Goddard Space Flight Center
**Raymond M. Hoff**, University of Maryland, Baltimore County
**Richard D. Ray**, NASA Goddard Space Flight Center
**Lynne Talley**, University of California, San Diego
**Bruce A. Wielicki**, NASA Langley Research Center

*The Earth Observer* staff joins the entire scientific community in congratulating these individuals on their outstanding accomplishments.

feature articles

# Freeing Clouds from Their Cages: The Cloud Object Approach to Satellite Data Analysis

*Kuan-Man Xu, NASA Langley Research Center, Hampton, VA, kuan-man.xu@nasa.gov*

## Introduction

When moist air is cooled to its dew point, water vapor condenses and clouds form. There are many different mechanisms in our atmosphere that can cause clouds to form, including turbulent motions, updrafts, mountain lee waves, mid-latitude fronts, tropical cyclones, and continental-scale overturning circulations. These phenomena occur over a wide range of scales—from as small as 1 m to as large as 10,000 km—which presents a challenge when scientists try and understand the roles that clouds play in regulating Earth's climate—scientists call these roles *cloud processes*.

The traditional method that scientists employ to help them study cloud processes is to define a latitude-longitude grid with a horizontal scale of a few hundred kilometers. Imagine the grid as the bars of a *cage* into which scientists try and "fit" clouds in order to study the *cloud processes* (through analyses of cloud properties such as monthly mean cloud fraction, liquid water content, radiative flux differences from clear sky conditions) that are at work. Of course, if you spend any time at all looking at clouds in the sky or on satellite images, you quickly realize that clouds usually don't take well to being confined to a cage. Clouds vary greatly in size and many are irregularly shaped, so no matter what size grid the scientists choose, some clouds won't fit.

A typical latitude-longitude cage would be large enough to capture many smaller scale clouds (e.g., individual thunderstorms) within each grid, but not large enough to capture a very large scale cloud (e.g., mid-latitude storms and tropical cyclones). These larger scale cloud systems have to be "split up" between several grid boxes. While this approach can and has been used with some effectiveness to study clouds over the years, there are problems. It turns out that important finer-scale details about the clouds can "slip through the bars" of the cage when one averages observational data over a grid. Scientists call these fine-scale details *subgrid-scale* processes since they operate at scales smaller than the scale of the grid used to represent them. Scientists need more observational data on these subgrid-scale processes to help them better understand how clouds "really work" to regulate climate and in turn improve the representation of *cloud processes* in computer simulations of the atmosphere that they use to forecast weather and predict climate change.

Recent Earth Observing System (EOS) satellites offer the potential to provide the data on subgrid-scale cloud processes that scientists desire, and offer a golden opportunity to advance our knowledge of the role that clouds play in regulating Earth's climate. However, the enormous amount of new data being returned by these missions also presents challenges when it comes to capturing and analyzing the data. For example, the data volume from the Clouds and the Earth's Radiant Energy System's [CERES; *Wielicki et al.* (1997)] 10-km footprint data product alone is more than two terabytes per year. For the higher resolution measurements of other instrument systems 1-km footprint data product, the data volume is increased by a factor of 100 over the 10-km data.

**Kuan-Man Xu**, **Takmeng Wong**, and **Bruce Wielicki** at Langley Research Center have been working on ways to circumvent the problems associated with processing these massive amounts of information. They were looking for a less data-intensive way to study clouds. They recognized that every cloud or cloud system forms in a unique dynamic and thermodynamic environment, and that it was probably best to study each cloud or cloud system—they called them *cloud objects*—individually rather than the traditional approach of considering spatial averages of clouds around the globe. In a sense, they were looking for a way to "free clouds from their cage"—i.e., instead of forcing clouds to "fit" into a predefined cage, could they custom design a cage to "fit" each individual cloud? The new *cloud object approach* that Xu and his colleagues developed not only greatly reduces the data volume—between 100 and 100,000[1] times less data to process—but has the added benefit that subgrid-scale details about each cloud can't "slip through the bars" of the cage. No matter how large a cloud or cloud system is, it always fits into a single grid so that no averaging of observations is necessary and finer scale details are preserved.

What follows is a description of our new *cloud object approach* to studying clouds, discussion of cloud physical properties diagnosed using the new technique, and conclusions based on the research. Various references appear throughout the article, and the reader is referred to these journal articles for additional details on this research.

## The Cloud Object Approach

The *cloud object approach* identifies a *cloud object* as a contiguous patch of cloudy satellite footprints on a

[1] The data volume is reduced by a factor of 100,000 only in cases where the data for describing the spatial distribution of cloud systems are not preserved.

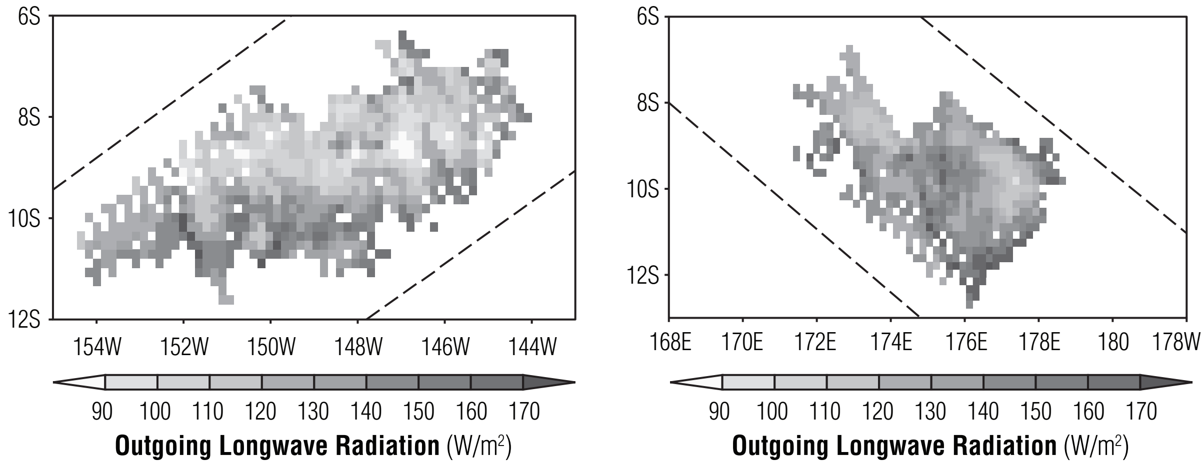


**Figure 1:** Horizontal distribution of outgoing longwave (infrared) radiative fluxes for two tropical deep convective cloud objects in the Pacific. The dashed lines show the boundaries of the TRMM satellite swath.

satellite swath for a specified cloud-system type. With this new approach, the shape and size of a cloud object are determined by the satellite footprint data and by the chosen selection criteria for that type of cloud system—no grid information is used. The choice of selection criteria is primarily dictated by some physical characteristics of the cloud system itself, which can be used to describe a *broad cloud-system type*. Once a *broad cloud system-type* is chosen, cloud objects within this type can be further classified into *subtypes*, for example, by the spatially and temporally matched environmental conditions.

Xu and his group looked at data from the CERES instrument to define cloud objects for this analysis. We used data from the CERES on the Tropical Rainfall Measuring Mission (TRMM) covering the periods January-August 1998 and March 2000 [*Xu et al.,* 2005] and also looked at data from CERES on Terra for March 2000-February 2002. (The January-August 1998 period corresponds to the peak and dissipative phases of the strong 1997-1998 El Niño while the March 2000 period corresponds to a weak La Niña condition.)

Based on the analysis of CERES data, four *broad cloud system types* have been identified from the CERES data. The four types of cloud objects are *deep convective cloud objects* and three different *boundary-layer cloud object* types: *cumulus*, *stratocumulus*, and *overcast*. The *deep convective cloud objects* are characterized by large cloud optical thickness (> 10); high cloud-top heights (> 10 km); and are located in the latitudinal band between 25° S and 25° N. The three types of *boundary-layer cloud objects* are all characterized by cloud top heights less than 3 km and located in the latitudinal band between 40° S and 40° N. The three *boundary-layer cloud object types* are distinguished by looking at cloud fraction: 0.1–0.4 defines *cumulus*, 0.4–0.99 defines *stratocumulus*, and 0.99–1.00 defines *overcast*. The cloud fraction of a particular footprint (average area of 10 x 10 km) is determined using data from high-resolution (1x1-km) imager instruments[2] aboard the same satellite [*Wielicki et al.,* 1997].

**Figure 1** shows examples of tropical convective cloud objects observed by the Tropical Rainfall Measuring Mission (TRMM) satellite in March 1998. The dashed lines on this figure show the boundaries of the TRMM satellite swath. Notice the irregular shape of each cloud object and the large spatial variations of outgoing longwave (infrared) radiation flux.

**Figure 2** shows the numbers of cloud objects and footprints in 5° x 5° areas[3] of the Pacific region for all *tropical convective cloud objects* with equivalent diameters greater than 100 km [see *Xu et al.* (2007) for further details]. For January–August 1998, the total number of *cloud objects* identified is 2257 while the total number of satellite footprints is 1.2 million.[4] The data shows that *convective cloud objects* occur mainly to the south of the Equator in the central and western Pacific and to the north of the Equator in the eastern Pacific. The first preferred location is due to seasonal cycle as the maximum solar radiation is located to the south of the Equator in these months. The second preferred location can be attributed to the influence of El Niño. During an El Niño, the pool of warm water shifts to the eastern Pacific and sea surface temperature increases, leading to enhanced convection—i.e., more

[2] For TRMM, data from the Visible and Infrared Scanner (VIRS) was used—which has a resolution of 2 km x 2 km. For Terra and Aqua, the Moderate Resolution Imaging Spectroradiometer (MODIS) was used.

[3] The accumulated numbers of cloud objects and footprints are based the center location of a cloud object, which means that some parts of a cloud object may be located at adjacent areas.

[4] The cloud object data are available online at: *cloud-object.larc.nasa.gov*. The web site provides interactive graphics for viewing individual cloud objects.

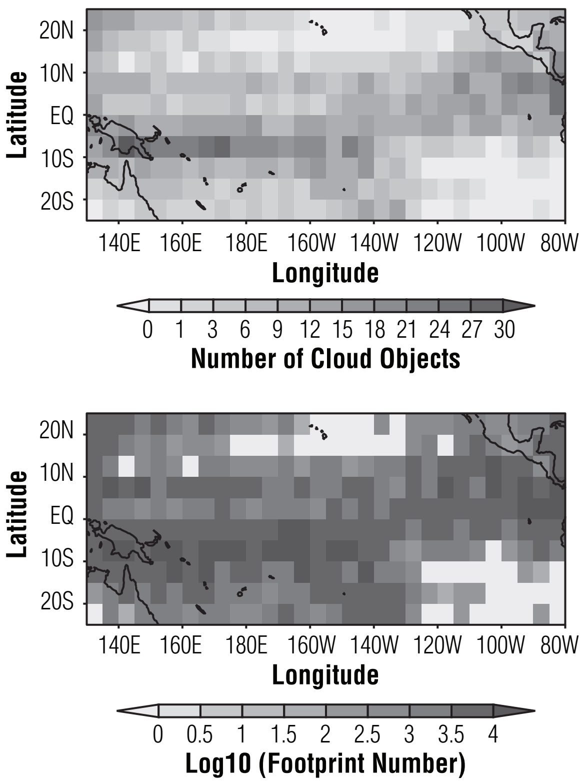


**Figure 2:** The numbers (top panel) and satellite footprints (bottom panel) of tropical convective cloud objects in 5° x 5° areas of the Pacific Ocean with equivalent diameters greater than 100 kilometers observed during January-August 1998.

tropical convective cloud objects. Notice that there are few *cloud objects* observed in the central Pacific between 15° N and 25° N and in the eastern Pacific between 10° S and 25° S. This can be attributed to subsidence associated with the Hadley (i.e., south-north overturning) and Walker (i.e., west-east overturning) circulations.

**Figure 3** shows the numbers of cloud objects in 5° x 5° areas of the Pacific region between 30° S and 30° N for all *boundary-layer cloud objects* with equivalent diameters greater than 75 km [see *Xu et al.* (2008) for further details]. For the January–August 1998 period, the total number of cloud objects was: 12026 *cumulus*; 26590 *stratocumulus*; and 10164 *overcast*. The corresponding total satellite footprint numbers are 1.1, 4.1 and 3.2 million respectively for these three cloud object types. The plots show that the central Pacific maximum and the westward extension of the maximum center in the Northern Hemisphere are related to the eastward migration of the Walker circulation during El Niño. The overcast cloud-object population is located farther eastward than the stratocumulus and cumulus populations, and the stratocumulus population is located farther eastward than the cumulus population, which matches well with what one would expect to see over the Pacific. (On a Los Angeles to Honolulu flight, the underlying overcast clouds near the coast gradually give way to small cumulus clouds further west.) These features are linked to both the longitudinal change in the strength of the subsidence and the geographic distribution of SST, in particular, the cold upwelling regions off the coasts.

## Cloud Physical Properties

The frequencies of occurrence of *cloud objects*, especially the proportion among the three boundary-layer cloud types—see **Figure 3**—are important characteristics of global distribution of cloud system types. For a detailed evaluation of the performance of models, however, scientists need to be able to assess how frequently certain values of cloud physical properties occur.

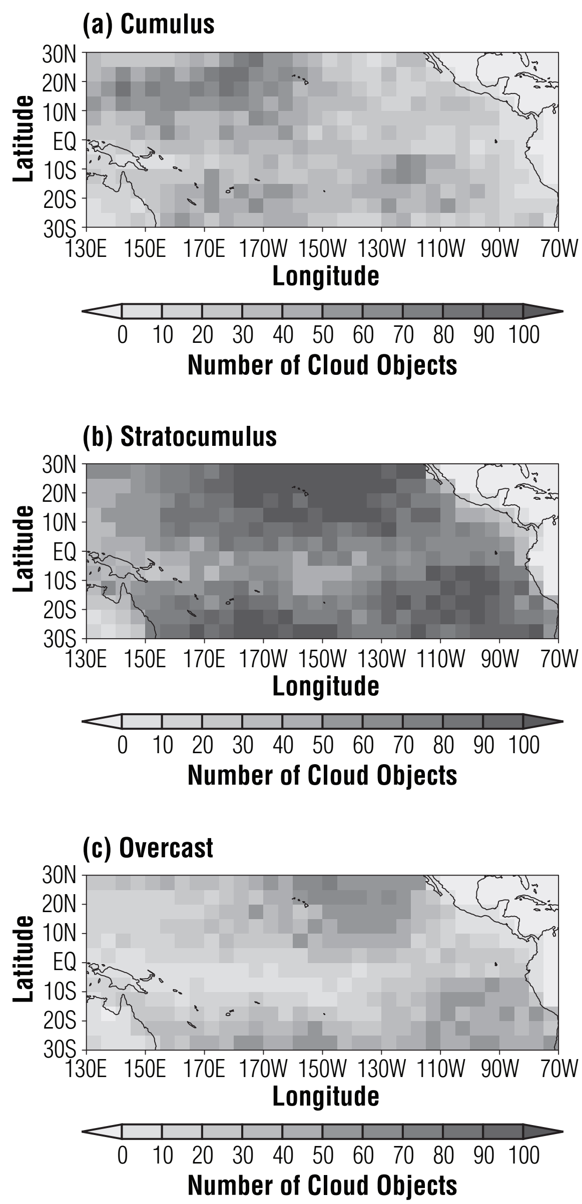


**Figure 3:** The numbers of cloud objects in 5° x 5° areas of the Pacific Ocean with equivalent diameters greater than 75 kilometers observed during January - August 1998. The top panel (a) is for the cumulus cloud objects, the middle (b) the stratocumulus cloud objects and the bottom (c) the overcast cloud objects.

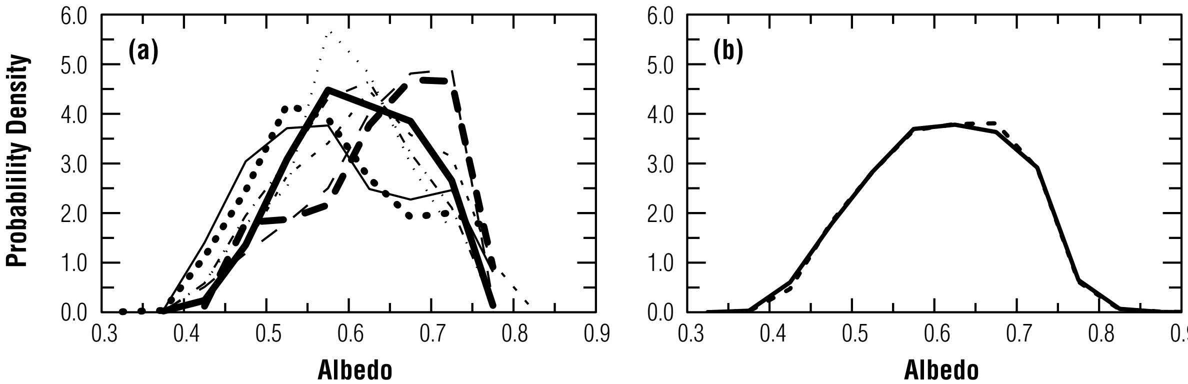


**Figure 4:** Probability density functions (PDFs) of TOA albedo for eight selected cloud objects of the tropical convective cloud-system type observed during January-August 1998 El Niño period are shown on the left panel (a) and summary PDFs of TOA albedo for the March 1998 (solid line) and March 2000 (dashed line) periods are shown on the right panel (b). Notice how combining large numbers of cloud objects smooths out some of the variability.

Thus, one of the tasks of the *cloud object approach* is to examine each cloud-system subtype and determine a range of possible values for each cloud physical property. (All of the cloud physical properties we are looking at have a finite range of possible values—scientists say that they have *discrete* values.) Once a range of values is set, scientists can assess how often each individual value occurs in the data—statisticians refer to this process as creating a *distribution* of the cloud physical properties.

Because we can't determine the probability that any single value will occur precisely, we have to instead determine how often a particular cloud property would fall within a small range around the value—i.e., the frequency of occurrence of that property. The possible values of each cloud physical property are divided up into a series of *bins*—so-named because they are analogous to a series of storage compartments which each "store" values falling within a certain range.[5] A bar diagram is constructed for the full range of the cloud physical property values, but the length of the bar is divided by the size of each *bin*. This end result is what scientists call a *normalized* frequency of occurrence of cloud physical properties from all *footprint* data within a cloud object. The normalized frequency of occurrence is also a *probability density function*, or PDF of cloud physical properties since the total integrated area under the curve is one. This approach will preserve all *subgrid-scale* cloud property information. All diagrams within a cloud system subtype will be combined to produce summary histograms or PDFs of cloud physical properties, instead of the simple averages and standard deviations of individual cloud objects.

The left panel of **Figure 4** shows examples of PDFs for top-of-the-atmosphere (TOA) albedo for eight *tropical convective cloud objects*. Since the dynamics of each cloud system (i.e., air flow) are different, there is quite a bit of variability among individual cloud objects. The right panel illustrates that some of the variability can be eliminated if one combines sufficiently large numbers of cloud objects, for example, over many monthly periods. The summary PDFs of TOA albedo for March 1998 and March 2000 are rather similar despite the fact that one happens during a decaying strong El Niño and the other during a weak La Niña. Other cloud properties such as cloud-top height and outgoing longwave (infrared) radiation flux, however, show more significant differences between the two periods [see *Xu et al.* (2005) for further details]. **Our research suggests that these observations are more useful to evaluate model performance than either the number of cloud objects or the number of satellite footprints alone.**

In addition to evaluating model performance as has been described above, because the data are not composite averages of very different types of cloud systems, the *cloud-object approach* also has the potential to greatly simplify the understanding of cloud-climate feedback processes—i.e., the impact the changes in clouds have on climate and vice versa. The changes in the *feedback strength*, which is defined as the rate of change of cloud physical properties with the atmospheric state, are then a combination of the changes in the frequency of occurrence of each individual cloud-system type and the changes in cloud physical properties of the same cloud-system type. If cloud physical property PDFs do not change with the atmospheric state, the changes in the frequency of occurrence of each type solely determine the overall changes in cloud physical properties—see **Figure 5** for an example. The diagnosed PDFs (right panel) of TOA albedo, liquid water path and cloud optical depth for the combined cloud object types are obtained using the observed proportions of the three boundary-layer cloud objects along a Pacific transect (starting from the coast of central California to the central Equatorial Pacific) and the observed PDFs of TOA albedo, liquid water path, and cloud optical depth over the entire subtropics for the three cloud-object types.

[5] The probability distribution is created by looking at the frequency that the cloud property value falls within a small range—or *bin*—around $(x - 1/2\Delta x, x + 1/2\Delta x)$—where $x$ represents the actual value and $\Delta x$ represents the size of each *bin* as discussed in the text above.

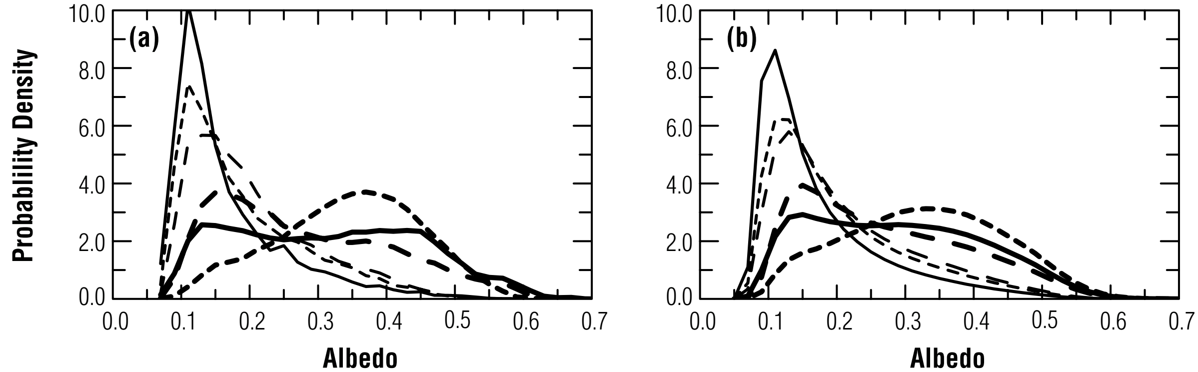


**Figure 5:** Summary histograms of TOA albedo for the combined cloud object types for six 6° x 6° areas along a Pacific transect starting from the coast of central California (flattest curves) to the central equatorial Pacific (sharpest curves). The left panel (a) is the observations while the right panel (b) is the diagnoses from the observed proportions of cloud object types and the observed summary histograms over the subtropical Pacific.

It reveals that diagnosed PDFs of the combined cloud object types are nearly identical to those observed (left panel) over 6° x 6° areas [see Xu *et al*. (2008) for further details]. **These results indicate that the key parameter to determine in order to obtain the rate of change of these cloud parameters is the rate of change of the proportion of the three boundary-layer cloud-object types with the atmospheric state.**

## Conclusions

The *cloud-object approach* to satellite data analysis selects specific types of cloud systems from satellite data without regard to the grids and does not average the data over time. This advanced data product can be used in two major areas. One of the areas is to improve the treatments of cloud processes in atmospheric models. Models can be tuned for a few cases, as many modelers do, with the expectation of some improved performance. But it will be more difficult to do so for hundreds or thousands of cloud object cases or cloud object subtypes. The ability to quantify the errors as a function of the atmospheric state is expected to be a powerful tool in pinpointing model problems.

The *cloud-object approach* should also enhance our ability to study the cloud-climate feedback processes directly for a single cloud-system type, as opposed to the multiple cloud-system types that are often simultaneously present in a fixed grid of the Earth using monthly, seasonally, or yearly averaged satellite/surface data. Thus, the feedback strength can be accurately determined for each cloud type or climate regime because of the availability of thousands of cloud objects. Once their relative proportion is known, the feedback strength can also be obtained for the combined cloud object type.

## Acknowledgments

This work receives support from the NASA Science Mission Directorate's Research and Analysis programs managed by **Don Anderson** and **Hal Maring** [both at NASA Headquarters]. The author would also like to thank **Takmeng Wong** [NASA Langley] for redrawing **Figures 1, 2** and **3**.

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# Landsat Science Team Meeting Summary

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**Meeting Overview**

The Landsat Science Team—sponsored by the U.S. Geological Survey (USGS) and NASA—met January 8–10, 2008, at the USGS Earth Resources Observation and Science (EROS) Center near Sioux Falls, SD. The meeting objectives were to:

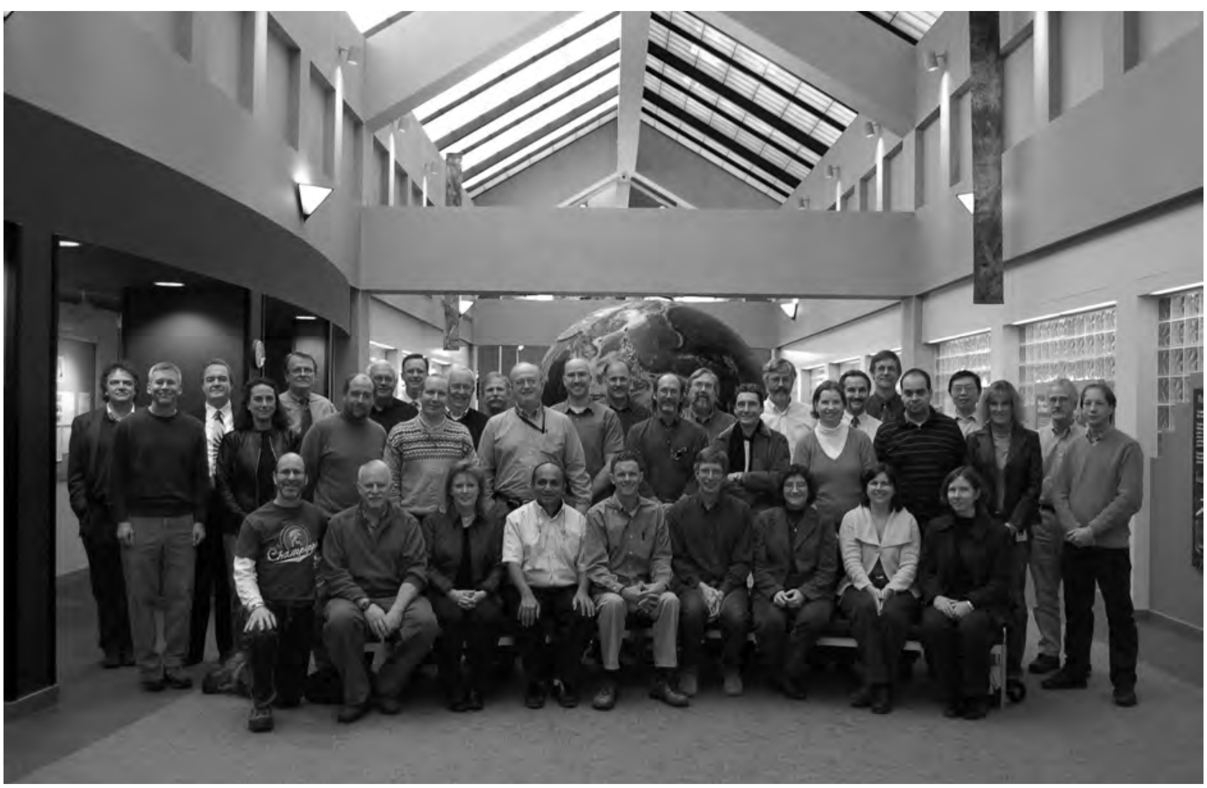
- review recent USGS and NASA Landsat Data Continuity Mission (LDCM) implementation steps and Landsat activities;
- review Landsat archive practices and opportunities with special emphasis on establishing a global consolidated Landsat archive and ensuring consistent data formats, access, and policies for all Landsat data holdings (Landsat 1–8); and
- provide recommendations on LDCM, Landsat, and other issues and opportunities.

The meeting agenda and presentations are available at: *ldcm.usgs.gov/january2008MeetingAgenda.php*

**Introductory Comments**

**Tom Loveland** [USGS—*Landsat Science Team*] initiated the meeting with a review of the issues that the Landsat Science Team addressed and provided inputs to NASA and the USGS since the June 2007 meeting. The topics and outcomes included:

- *Landsat data policy*: The Team provided input on content and wording that USGS and NASA incorporated into the recently approved data policy.
- *Landsat-LDCM archive continuity and consolidation*: USGS is implementing a plan to make all Landsat data available at no cost via the Internet.
- *Standard product pixel dimensions*: USGS has accepted the Team's recommendation to change standard product pixel dimensions to 15- and 30-m rather than the current 14.25- and 28.5-m sizes.
- *Cloud cover cut-off specifications*: USGS agreed to raise the cloud threshold for no-cost Landsat 7 standard products from 10% to 20% and will make scenes with higher amounts of cloud cover available using on-demand processing.
- *LDCM standard product requirements*: The Team assessed the science and applications value of a lower level LDCM standard product (e.g., Level 0) and recommended adding one to the LDCM product suite. USGS and NASA concluded that there is benefit to the additional product, and an analysis of cost and schedule impacts is being carried out.



**Curtis Woodcock** [Boston University—*Landsat Science Team Leader*] set the tone for the meeting by emphasizing the importance of viewing Landsat and LDCM in the same context. He urged the Team to contribute to LDCM requirements studies and to help ensure that all Landsat products will be available with consistent formats, access strategies, and data policies.

**Landsat 5 and 7 Status**

**Kristi Kline** [USGS—*Landsat Project Manager*] provided an update on the status of Landsats 5 and 7. Landsat 5 imaging was suspended in October 2007 due to a loss of a cell from one of two batteries. The Landsat flight operations staff is working on a solution and a new operations strategy. Resumption of Landsat 5 acquisitions is scheduled for February 2008.[1] Other than the 2003 Scan Line Corrector (e.g., SLC-off) anomaly, Landsat 7 is fully functional and continues to collect extensive global coverage. Kline reported that the pilot activity that provided no-cost Landsat 7 Enhanced Thematic Mapper Plus (ETM+) SLC-off data (May 2003 through the present) for the U.S. has been continued and expanded. The pilot originally consisted of data with less than 10% cloud cover but was expanded in October 2007 to scenes with 20% or less cloud cover. The pilot is the first step toward making all Landsat data in the USGS archive available via the Internet at no cost (see Landsat Archive Discussion).

**Jeff Masek** [NASA Goddard Space Flight Center (GSFC)—*LDCM Deputy Project Scientist*] gave an update on the NASA–USGS Global Land Survey (GLS) 2005 initiative. The GLS-2005 activity is a continuation of the Landsat *GeoCover* orthorectified global dataset (1975, 1990, and 2000 epochs) and adds 2005-era global Landsat to the GLS archive. The original *GeoCover* data for the three periods are being reprocessed to improve geometric accuracy through improved Shuttle Radar Topography Mission digital elevation models and additional ground control. The reprocessed data are based on 15-, 30-, and 60-m pixels rather than the 14.25-, 28.5, and 57-m pixel dimensions used previously. The 2005-era data will use the improved geometric baseline. The reprocessed North America data have been delivered (November 2007) and the initial validation indicates ~18-m root mean square error (RMSE) on a per-scene basis. All GLS products will be made available online at no cost to users. The data will be made available immediately after production and the first datasets should be released in late January 2008.

[1] Landsat 5 is now back on-line and the Thematic Mapper instrument is approaching normal operating temperatures.

**LDCM Status**

**Bill Ochs** [NASA GSFC—*LDCM Project Manager*] and **Mike Headley** [USGS—*LDCM Project Manager*] provided reports on the status of LDCM planning and implementation. The NASA and USGS team is working toward a launch readiness date of July 2011.

**Ochs** reported that the Operational Land Imager (OLI) development was awarded to Ball Aerospace and Technology Corporation (BATC) of Boulder, CO, in July 2007. Since the award, numerous subsystem peer reviews have been conducted and OLI systems requirements and integrated baseline reviews were successfully completed. The spacecraft procurement is in the final stages and a contract award is expected in early spring 2008. The contract for the launch vehicle, an *Atlas V*, was awarded to Lockheed Martin Commercial Launch Services of Littleton, CO, in October 2007. The request for proposals (RFP) for the final part of the space segment, the Mission Operations Element, will be released soon and an award decision is expected in early Summer 2008.

NASA and the USGS are involved in a number of reviews of LDCM systems. The USGS completed the ground system requirements review and is now conducting the ground system element requirements reviews. The system requirements reviews are examining the functional and performance requirements defined for the LDCM systems. Ochs said that the Mission Definition Review (MDR) is scheduled for April 2008. The MDR is a formal examination of the proposed requirements, the mission architecture, and the flow down to all functional elements of the mission to ensure that the overall concept is complete, feasible, and consistent with available resources.

Ochs also discussed the status of two additional instruments that are being considered for the LDCM spacecraft. The Thermal Infrared Sensor (TIRS) would provide two thermal channels with 120-m resolution and would provide much needed continuity with past Landsat thermal measurements. NASA has completed studies that resulted in the development of a feasible concept, but no funds are available to continue the planning or to build TIRS. The LDCM spacecraft specifications require the capability for carrying the TIRS instrument. **A decision to add TIRS to the LDCM payload at this time would likely delay the LDCM launch by at least a year.**

The second instrument is the Total Solar Irradiance Sensor (TSIS), which consists of the Total Irradiance Monitor (TIM) and the Spectral Irradiance Monitor (SIM). TSIS was originally planned for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) platform but was removed. The Office of Science and Technology Policy recommended placing TSIS on any available and suitable vehicle in time to overlap with the Glory mission; LDCM is the prime candidate. The purpose of TSIS is to improve the understanding of the sun–Earth climate connection.

**Jeanine Murphy-Morris** [NASA Goddard Space Flight Center—*OLI Instrument Manager*] provided an overview of OLI characteristics, status, and schedule. Baseline instrument design characteristics include:

- Pushbroom instrument with 9 channels ranging from 443 nm to 2200 nm;
- four-mirror telescope;
- focal plane array consisting of 14 sensor chip assemblies;
- solar calibrator to be used once per week;
- intra-orbit calibration lamps;
- dark shutter for offset calibration; and
- twelve-bit resolution.

The telescope optical design has been completed; contracts are in place for the optical bench; and the primary, secondary, and quaternary mirrors are being polished, while the tertiary mirror light weighting is nearing completion. The preliminary design review for key focal plane array components (detector and readout integrated circuits) are complete as is the peer review of filters. Plans for algorithm and integration and test functions are also underway.

**Headley** reported that the ground systems requirements review was successfully completed in September 2007 and the element requirements reviews are now underway. The ground system preliminary design review is targeted for September 2008. Headley also provided an update on key ground systems procurements.

Ground antenna and network services procurements are planned for mid-2008, and the flight operations team procurement Request for Proposal (RFP) will be released in spring 2008 with a contract award planned for late summer 2008.

Finally, Headley summarized discussions with representatives of the International Cooperator (IC) network regarding their interest in LDCM. IC respondents included Argentina, Australia, Brazil, Canada, China, European Space Agency, German Aerospace Center, Hiroshima Institute of Technology in Japan, Remote Sensing Technology Center of Japan, South Africa, and Thailand. All expressed interest in continuing as ICs in the LDCM era and prefer to receive LDCM data via a direct downlink. While some expressed interest in also receiving Level 1T data via the Internet, many ICs desire having control over processing specifications. The ICs expressed their support for thermal imaging capabilities. IC representatives will be invited to future Landsat Science Team meetings.

**Ed Grigsby** [NASA Headquarters—*Landsat Program Executive*] and **Jim Irons** [NASA GSFC—*LDCM Project Scientist*] led a discussion on recent reviews within NASA on LDCM and OLI schedule issues and risks. The LDCM schedule is driven by the need to minimize a data gap with Landsat 7. Since a data gap could occur at any time, the LDCM instrument schedule is very aggressive. The resulting risks associated with the aggressive schedule are recognized and NASA has been conducting a requirements analysis to determine options for potential risk reduction and mitigation. Specific elements that could affect the launch readiness date include the addition of TSIS and TIRS, and OLI specifications dealing with the coastal aerosol and cirrus bands, pixel-to-pixel uniformity, radiometric stability, and signal-to-noise ratios. The Landsat Science Team was asked to provide input to NASA management on these issues.

The Team found value in all of the targeted capabilities and reiterated the benefits of adding a thermal infrared sensor. The Team recognized the value of the new coastal band for coastal and inland lake water quality monitoring as well as the potential for improving the atmospheric correction of the other OLI bands. Similarly, the new short-wave infrared band for cirrus cloud detection will improve the ability to account for ice–cloud attenuation of the signal received in the other OLI bands. The Team also concluded that across track pixel-to-pixel uniformity and radiometric stability are essential to detecting and characterizing land cover change, while the specified signal-to-noise ratios will substantially advance capabilities to recognize and characterize land cover.

The Team agreed that current spectral band and radiometric performance requirements should be relaxed or waived only if the full achievement of the requirements does not jeopardize the overall mission and the ability to observe the 2012 growing season. Small departures from specification may be acceptable in some cases, but dramatic degradations in performance might compromise the entire mission. The Team also values the inclusion of the thermal sensor if the development and integration can be completed in time for LDCM to reach operational status by March 2012. The addition of TIRS could add up to a year of additional development time. **A delay of a year is not acceptable, and the Landsat Science Team suggested that NASA find and implement other approaches for restoring the thermal imaging capabilities provided by Landsats 5 and 7.**

**Landsat Archive Discussion**

A special focus during the meeting was a review of Landsat archive practices and opportunities with special emphasis on establishing a global consolidated Landsat archive and ensuring consistent data formats, access, and policies for all Landsat data holdings. **Ray Byrnes** [USGS—*Liaison for Satellite Missions*] led off the topic with a summary of the recently implemented USGS–NASA Landsat Data Distribution Policy. The policy concludes, *"in accordance with OMB Circular A-130 and the USGS Data Policy, the USGS provides selected satellite data products for retrieval via the Internet at no charge to users."* This sets the stage for significantly expanded access and use of the Landsat archive for science and applications.

**Kristi Kline** explained that the USGS is beginning to phase in no-cost access to all archived Landsat data (July 1972 to present). The USGS-operated Landsat archive currently includes close to 2.2 million scenes, or over 1,100 terabytes of data. Access to the archive will be staged incrementally as system conversions, calibration strategies, and other implementation issues are resolved. The images will be in a rolling data pool or processed using an on-demand strategy based on a single L1T product definition (calibrated, terrain corrected, orthorectified to a Universal Transverse Mercator projection, and 15-, 30-, and 60-m pixels resampled using cubic convolution). LDCM data will also be processed to the same L1T specifications. Once the transition is completed, all Landsat data held in the USGS National Satellite Land Remote Sensing Data Archive will be available in electronic format over the Internet to anyone at no cost.

The next Landsat archive issue discussed dealt with assembling a consolidated global Landsat archive. While the USGS archive of global coverage is extensive, there is a significant amount of coverage held by Landsat ICs. **Steve Labahn** [USGS— *International Ground Station Network Manager*] gave an overview of the current IC network and discussed its role, capabilities, and expectations in the global Landsat ground network. Twelve ICs are receiving Landsat 5 TM data and nine are collecting Landsat 7 ETM+ data.

**Steven Covington** [The Aerospace Corporation—*Landsat 5 & 7 Flight Systems Manager*] presented an evaluation of the process, cost, and relative merit for consolidating a copy of the global archive of historical Landsat imagery at EROS. International ground stations have collected Landsat scenes since the launch of Landsat 1 in July 1972. Over the past 35 years, over 50 ground stations have been configured to receive Landsat data. There are nine historical collection sites operated by seven organizations that likely have some significant, unique historical Landsat data not duplicated in the USGS Landsat archive. There is also growing concern about the state of the historical international archives, especially at inactive stations where there are no active contacts. It is clear that a consolidated archive would have many benefits for global studies.

Covington explained that the global consolidated archive has several objectives.

- Determine the willingness of the ICs to participate in this effort.
- Determine the location, extent, and condition of the historical Landsat archives around the world.
- Generate a list of the instrument (return beam vidicon, MSS, TM, ETM+), data format, and media type at each location.
- Assess the equipment, software, logistics, and level of effort necessary to acquire, ingest, process, and archive the data.
- Develop an estimated cost and schedule for establishing a global consolidated archive.

This investigation is in the fact-finding stage. An update will be provided at future Landsat Science Team meetings.

The next topics involving the Landsat archive focused on radiometry and calibration. **Brian Markham** [NASA GSFC—*Landsat Calibration Scientist*] reported on the status of Landsats 5 and 7 radiometric performance. Markham concluded that Landsat 7 ETM+ performance is stable, except for changes induced by the switch to bumper mode operations. The switch made in April 2007 disrupted the ETM+ sensor alignment calibration. Prior to the switch, 97% of the scenes had better than 50-m Root Mean Square Error, but with bumper mode operations, only 65% of the scenes had better than 50-m RMSE. Markham also concluded that Landsat 5 TM performance was stable through October 2007 when imaging was suspended. With the January 2008 resumption of imaging, there will be a need for frequent bumper mode calibration. He also reported that Landsat 5 TM reflective and thermal band calibrations were updated in April 2007 and that the thermal band calibration accuracy since 1999 is now comparable to the ETM+ thermal band.

**Dennis Helder** [South Dakota State University—*Landsat Science Team Member*] briefed the Team on using Landsat 7 ETM+ to calibrate OLI data. Helder also presented a strategy for consistent calibration of the entire Landsat archive. The Government Calibration/Validation Plan defines scope, roles, and responsibilities. Essentially, NASA leads through commissioning and the USGS leads during operations. The plan specifies performing characterizations on every scene acquired. Because of the increase in the number of detectors, automation will be used to provide immediate alerts of the need to update calibration and warnings of instrument and product performance degradation. An overflight between Landsat 7 and LDCM provides the best opportunity for calibration continuity through cross-calibration. Cross-calibration with bridge sensors provides a limited capability to ensure consistent calibration. This, augmented with the use of pseudoinvariant sites for trending and vicarious calibration, may provide a second approach to bridging the gap. Helder recommended that a cross-calibration plan using Landsat 7 ETM+ and Landsat 5 TM with bridge sensors and with pseudoinvariant sites be developed and implemented.

Finally, Helder laid out a strategy for achieving the goal of having consistently calibrated data across the entire Landsat archive. The basic tenets of the strategy are as follows.

- Landsat 5 TM has already been consistently calibrated with Landsat 7 ETM+.
- Landsat 4 TM can be cross-calibrated to Landsat 5 TM due to the availability of coincident collections over multiple targets.
- Landsats 4 and 5 Multispectral Scanner (MSS) can be cross-calibrated with TM, but there will be complications due to differences in spectral response functions.
- Landsat 3 MSS calibration is a critical step for achieving consistent calibration for the first decade of Landsat observations. There are very few overlapping scenes available for using the *pseudoinvariant site approach* to link Landsat 3 to Landsat 4 MSS. The usefulness of onboard calibration information (e.g., calibration wedge) for instrument trending is unknown.
- Landsats 1 and 2 MSS calibration can take advantage of the substantial numbers of scenes over *pseudoinvariant* sites. The usefulness of onboard calibration information is also unknown.

The final Landsat archive related discussion involved the National Land Imaging Program (NLIP). **Bruce Quirk** [USGS—*Land Remote Sensing Program Coordinator*] gave a summary of NLIP history, status and plans, and opportunities for Landsat Science Team input. The NLIP concept is the outgrowth of the Future of Land Imaging Interagency Working Group that concluded that the United States: (1) must commit to continuing the collection of moderate-resolution land imagery; (2) should establish and maintain a core operational capability to collect moderate-resolution land imagery through the procurement and launch of a series of U.S.-owned satellites; and (3) should establish the NLIP, hosted and managed by the Department of the Interior (DOI), to meet U.S. civil land imaging needs. As defined, NLIP will *"serve the Nation by acquiring and providing operational land imaging capabilities and applications to support U.S. economic, environmental, foreign policy, and security interests."* To achieve this goal, the DOI will:

- Oversee a Federal Land Imaging Council and Land Imaging Advisory Committee;
- manage U.S. land imaging requirements;
- acquire U.S. land imaging systems and data;
- develop new applications for federal, state, and local governments;
- investigate and develop new remote sensing technology;
- ensure data delivery to universities and scientists, nongovernmental organizations, and international organizations; and
- coordinate acquisition and data distribution plans with U.S. industry, foreign governments, and foreign commercial firms.

Above all else, NLIP will *"ensure availability, access, and ease of use of land imaging data for the Nation."*

Quirk concluded by asking the Landsat Science Team members to continue their efforts to advocate for Landsat capabilities and to provide specific input to NLIP by participating in the Land Imaging Advisory Committee, reviewing strategic plans, providing guidance on the Landsat 9 requirements definition process, contributing to the definition of the science component of NLIP, and developing new applications for federal, state, and local governments.

**Principal Investigator and Other Reports**

Several Landsat Science Team members and other researchers gave updates on their activities related to Landsat and LDCM. **Patricia Vornberger** [SAIC] presented the recently released Landsat Image Mosaic of Antarctica (LIMA) *lima.nasa.gov* that was produced by NASA, USGS, the National Science Foundation, and the British Antarctic Survey as a contribution to the International Polar Year. LIMA represents the first Landsat mosaic of Antarctica and was constructed from 1,100 Landsat scenes as well as MODIS imagery where Landsat coverage was unavailable.

**Feng Gao** [Earth Resources Technology, Inc.—*Landsat Science Team Member*] presented his research on developing a more robust land monitoring system. His approach is based on combined observations from multiple, international sensors. Gao uses the General Empirical Relation Model (GERM) to convert sensor digital numbers to surface reflectance directly using MODIS products as reference datasets. However, even with perfect calibration and atmospheric correction, direct comparison of surface reflectance from different sensors is still limited by viewing and illumination geometries, spectral band response function, geolocation accuracy, and resampling approaches.

**Richard Allen** [University of Idaho—*Landsat Science Team Member*] reviewed his investigation of methods for sharpening 120-m land surface temperature from Landsat 5 to 30-m resolution using normalized difference vegetation index (NDVI) inputs. The approach is based on using land surface temperature endpoints representing high NDVI (wet/cold) and low NDVI (hot/dry) conditions in an image. Allen concluded that sharpening creates no net bias to the original 120-m land surface.

**Lazaros Oreopoulos** [University of Maryland Baltimore County and NASA Joint Center for Earth Systems Technology—*Landsat Science Team Member*] gave an overview of the role of 1.38 µm observations for cloud detection. Using MODIS data, Oreopoulos showed that due to strong water vapor absorption, when no high clouds are present, radiation scattered by surface and low clouds is absorbed by water vapor, but when high clouds are present, the 1.38 µm signal is scattered and reaches the sensor. He concluded that quantitative use for cloud masking is difficult.

**David Roy** [South Dakota State University] summarized his NASA-funded project to create a consistent and seamless Landsat ETM+ data stream in near-real time for use in terrestrial monitoring applications. The strategy contributes to NASA's Land measurement theme by per-pixel quality assessment information and derived land cover characterizations at monthly and longer time periods.

**John Schott** [Rochester Institute of Technology—*Landsat Science Team Member*] reviewed resampling issues associated with the OLI. The USGS had previously determined that the standard product would use cubic convolution resampling. Schott revisited this decision and concluded that because of the change to pushbroom technology and the inherent challenges associated with accounting for terrain spectral sampling and timing, cubic convolution is more appropriate than nearest neighbor or bilinear resampling.

Schott's presentation stimulated a follow-up discussion on the merits of using a predefined tessellation where spectral data are populated to form a point on the ground rather than being sensor specific. This should provide greater geometric consistency for temporal investigations. The USGS agreed to evaluate the feasibility of a predefined grid.

**Bryan Bailey** [USGS—*Principal Scientist*] summarized the work of the Committee on Earth Observation Satellites (CEOS) Land Surface Imaging Constellation Study Team. The CEOS Constellation concept was initiated to enhance effective planning and development of future Earth observing systems by maximizing international collaboration without eroding the independence of individual space agencies. The Land Surface Imaging Constellation seeks to promote the effective and comprehensive collection, distribution, and application of space-acquired image data of the global land surface. This is expected to be met through cooperative enhancement of data access, coordinated data acquisition planning, and cooperation in ground segment planning.

**Meeting Conclusions**

**Curtis Woodcock** provided the meeting wrap-up by summarizing the discussions, conclusions, and actions. The key outcomes included the following.

- Meeting the current launch readiness date is the top priority and any discussion regarding OLI and other specifications must consider impacts on launch. **The Team also concluded that LDCM must be operational by March 2012 so that it is available for use during the Northern Hemisphere growing season.** A letter will be sent to NASA and the USGS expressing this view. The Team also concluded that consideration of additional payloads (e.g., TIRS, TSIS) that could delay launch should be discontinued. This will also be expressed to NASA.

- A letter expressing enthusiastic support for DOI and USGS efforts to open the access to the Landsat archive and the completion of the new data policy stating the change to no-cost Landsat standard products over the Internet will be sent. The actions will significantly increase the value of Landsat for a wider range of science and applications.

- The Team agreed to investigate key OLI performance parameters including the effects of changes in signal-to-noise ratios on land cover characterization accuracy and the applications benefits of the coastal aerosol and cirrus bands.

Other follow-up activities include assisting in identifying contacts that may be familiar with inactive ICs, providing recommendations for potential pseudoinvariant calibration sites, contributing evaluation criteria for determining the pros and cons of predefined tessellations, and identifying science opportunities in the NLIP era.

The next Landsat Science Team meeting will be held July 15–17, 2008, in the Washington, DC, area. The meeting will focus on OLI, NLIP, and principal investigator research. ■

# ASTER Science Team Meeting Report

*Michael Abrams, Jet Propulsion Laboratory/California Institute of Technology, Michael.J.Abrams@jpl.nasa.gov*

*The 32nd Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting was held December 3-6, 2007 in Kailua-Kona Hawaii. About 65 participants attended the meeting. The weekend before the meeting,* ***M. Ramsey*** *[University of Pittsburgh and University of Hawaii] arranged field trips to Kilauea volcano and the Hawaii Volcano Observatory. After the meeting there was a field trip planned to the top of Mauna Kea to visit the observatories.*

**Opening Plenary**

**H. Tsu** [Earth Remote Sensing Data and Analysis Center (ERSDAC)] and **M. Abrams** [Jet Propulsion Laboratory (JPL)] welcomed U.S. and Japanese ASTER Science Team members, U.S. Government attendees, and interested parties to the 32nd ASTER Science Team Meeting.

**Abrams** reviewed new ASTER Science Team membership based on the 2006 research announcements. Four new members were selected: **M. Pritchard** [Cornell University], **J. Masek** [Goddard Space Flight Center (GSFC)], **R. Crippen** [JPL], and **S. Tulaczyk** [University of California Santa Cruz]. The JPL ASTER project was funded for two years through NASA's Senior Review process for FYs 2008 and 2009.

**T. Sato** [Japan Resources Observation System Organization (JAROS)] reported on instrument status, particularly problems with the shortwave infrared (SWIR) cooler to be discussed in detail later. Everything else was performing nominally.

**M. Hato** [Earth Remote Sensing Data and Analysis Center (ERSDAC)] reported on the operational status of the Japan Ground Data System. Data scheduling and production were nominal.

**M. Fujita** [ERSDAC] reported on scheduling status, including the Global Map-3, Global digital elevation map (DEM) data acquisitions, gap-filler acquisitions, and the nighttime thermal infrared (TIR) data acquisitions. Each would be discussed during the working groups, and updated actions decided.

**T. Tachikawa** [ERSDAC] talked about further progress on the Global DEM, including schedules and start date. The first Level 1A data were delivered to Sensor Information Laboratory Corp. (SILC), and DEM production has commenced.

**Ramsey** gave a special talk on use of full-mode nighttime data to map and characterize the most recent Kilauea lava flows and eruptions. Results allowed the U.S. Geological Survey (USGS) to complete their maps of activity.

**Operations and Mission Planning Working Group**

**Fujita** reviewed progress on the Global Map-3 Science Team Acquisition Request (STAR). There was a discussion about starting a new Global Map, but team members decided to continue with Global Map-3. He reviewed progress on the Global DEM STAR, and it is satisfactory. The Nighttime Thermal Infrared STAR is going well. The Operations and Mission Planning (OMP) group will wait for a report from the Temperature/Emissivity Separation (TES) group to decide how to continue. The Gap-filler STAR ended with good progress. It was recommended to re-submit it for next year, and to look for any gaps in the Southern Hemisphere.

**Hato** reported on monitoring of buffer filling of the solid state recorder (SSR). The maximum was 98%, so we will maintain the current settings.

**Sato** went over the SWIR re-cycling plans, similar to his presentation at the opening plenary session.

**Tachikawa** presented details of his study to change all of the STARs to *Low2* gain for the SWIR. Most of the large STARs (Global map, glaciers, volcanoes) can be changed easily. There are a few hundred smaller STARs that will require manual intervention. Tachikawa will prepare a list of all active STARs for review by the Science Team. Unused STARs will be eliminated, some will continue with current gains, the remainder will be re-submitted with *Low2* gain for SWIR.

**Abrams** and **L.Maldonado** [JPL] reported on a draft version of a Data Acquisition Request (DAR) user survey. The survey will be sent to U.S. DAR users through a web interface, and results will be reported at the next team meeting.

**K. Duda** [Land Processes Distributed Active Archive Center (LPDAAC)] reviewed the status of the Direct Downlink (DDL) test. The next attempt is scheduled for January 28, barring any conflicts with other activities, like SWIR recycling or Shuttle flights.

**L1/DEM Working Group Level**

**H. Fujisada** [SILC] reported on results from several different Japanese contractors who evaluate ASTER geometric performance and on the status of Level 1 (L1) software. The contractors found no problems in the L1 software. Inter- and intra-telescope registration errors are nominal and well within required limits. Examination of SWIR data acquired with *Low2* gain indicates that the lower signal-to-noise causes an increase in the parallax correction accuracy.

**B. Bailey** [USGS] revealed that DEM and orthorectified products produced at the LPDAAC are going out in satisfactory numbers. A few features in DEM products were noted, and were under investigation.

**Hato** reported that ERSDAC had delivered 110,000 L1A scenes to SILC for Global DEM processing. Every 3 weeks, another delivery of 110,000 scenes will be made until the entire archive is transferred.

**Tachikawa** showed additional validation of the Global DEM in Japan with added control points. Accuracy was unchanged form June report.

**Fujisada** described the status of the Global DEM project. Final delivery of the 23,000 1° x 1° tiles should be at the end of May, 2009.

**Crippen** showed previous work he had done using ASTER DEMs to fill holes in Shuttle RadarTopography Mission (SRTM) DEMs. Results were very satisfactory.

**SWIR Processing Special Meeting**

The team held a special session to discuss data processing issues involving compromised SWIR data.

**Hato** reported that there were many impacts upon the data products, starting with Level 0 processing. Best case is if SWIR is still *on*, even if data are 0's or 255's. Hato presented analysis of impacts if SWIR instrument powered *off*. A test done during the October recycle allowed visible and thermal data to be processed manually while full mode data were captured and transmitted. Changes that will be needed include: reengineering of the scheduler; reengineering of the L1A software; and reengineering the tape archive control system.

**Duda** reported that 13 of 19 LPDAAC ASTER products will be affected if no SWIR data are available. The impacts range from needing to eliminate a product entirely, to modifying a product. Much work needs to be done to mitigate these impacts.

**Tachikawa** reported that some of the cloud assessment algorithms would be affected by lack of SWIR data; the main impact would be separating snow/ice from cold clouds.

**B. Eng** [JPL] said that impacts at JPL would be similar to the Duda assessment but changes to production software may not require a huge effort.

**K. Thome** [University of Arizona] discussed the impact of the SWIR problems on higher level SWIR products. Since SWIR data are not used as derivative for any other products, the impact only requires eliminating products—e.g., SWIR reflectance.

**Temperature-Emissivity Separation Working Group**

**A. Mushkin** [University of Washington] presented a calibration method for roughness data extracted from ASTER stereo images and showed how it could be used to correct TIR emissivity data for loss of spectral contrast arising from multiple scattering. The roughness data are based on shadowing differences between the nadir and back-looking images and are an unintended serendipitous product from ASTER bands 3N and 3B, designed to produce DEMs.

**H. Tonooka** [Ibaraki University] reported on the effort to mosaic emissivity images in Asia. Single-frame and stacked-frame mosaics were analyzed. Stacking allows better statistical characterization. *Mosaiced* emissivity products have important applications to the broader community for temperature recovery and energy-balance calculations.

**G. Hulley** [JPL] reported on the JPL seasonal emissivity mosaics of California for the summer and winter seasons. Mosaics were based on the TES standard emissivity product and an advanced cloud screening procedure. An analysis of one season for California was completed using 800+ standard data products.

**A. Gillespie** [University of Washington] gave a progress report on investigations at the University of Washington into the nature and behavior of temperature/emissivity fields represented by image data at remote-sensing scales. A TIR radiosity model was created and tested using forward looking infrared (FLIR) broadband and Telops hyperspectral field images. Results can be used to interpret ASTER temperature and emissivity data more closely.

**Tonooka** reported that cloud masks for ASTER nighttime scenes are inaccurate. He discussed the success of using the MOD35 11-km Cloud Mask Products to improve the accuracy of the 1-km ASTER cloud mask for the ASTER database.

**Tonooka** also led a discussion of the best plan to complete the global nighttime TIR acquisition. The highest priority will include Saudi Arabia and northern Australia, and then Brazil. Recommendations were made as to how best to organize the plans submitted to the Operations and Mission Planning Working Group (OMPWG) and two new Action Items were generated.

**Geology Working Group**

**Mushkin** used ASTER stereo data to determine sub-pixel surface roughness, and thus estimate erosional surface age and roughness corrections for TIR data. Using this technique he derived a slip rate that was four times faster than previously estimated.

**W. Sneed** [University of Maine] talked about studies of glaciers in Canada and Greenland to determine volume changes, elevation changes, and ice velocity changes. The studies used data from ASTER, Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat.

**D. Adams** and **M. Eneva** [both from Imageair, Inc.] discussed their studies to investigate possible thermal precursors to earthquakes in California. No unique thermal signatures have been found related to earthquakes.

**J. Mars** [USGS] compared new ASTER cross-talk corrected data products with Visible/Infrared Imaging Spectrometer (AVIRIS) recovered spectra. Differences were attributed to incorrect atmospheric water vapor models. He also discussed his regional alteration mapping in Iran using techniques developed and validated in Nevada.

**F. Kruse** [Horizon GeoImaging, LLE] talked about nested hyperspectral/ASTER mineral mapping techniques. Using Airborne (AVIRIS) data, ASTER is used to extend results regionally. While ASTER does not have the ability to map nearly the same number of minerals, the technique is a vast improvement over existing methods.

**B. Raup** [National Snow and Ice Data Center] provided an update on the Global Land Ice Measurement from Space (GLIMS) project. GLIMS now involves 140 people in 20 countries, studying glaciers worldwide.

**Ramsey** described his project to use the ASTER *urgent request protocol* for volcano monitoring in Alaska and Siberia. The data are provided to the Alaska Volcano Observatory for use in their ash hazard assessments for aircraft safety.

**Ramsey** also talked about recent ASTER observations of Kilauea eruption activity, and the use of full-mode nighttime data to characterize the volcanic activity.

**M. Watson** [University of Bristol] discussed modeling the limits to detect sulfur dioxide ($SO_2$) using ASTER TIR data by studying two adjacent volcanoes in Guatemala. The limit seems to be about 500 tons/day.

**R. Wessels** [USGS] reported on seven years of ASTER observations of Pavlof and Mount Hague volcanoes in Alaska. These tend to be low temperature anomalies, and provide constraints on ASTER's ability to detect anomalies.

**Eneva** discussed using ASTER TIR data to look for geothermal anomalies in the California Coso geothermal field. Many environmental factors conspire to confuse true geothermal heating signals with other false positives.

**M. Urai** [National Institute of Advanced Industrial Science and Technology (AIST)] talked about thermal anomalies associated with the Merapi volcano and its 2006 lava dome. He used day and night TIR data as well as DEMs for his analyses.

**Abrams** reported on behalf of **G. Vaughan** [JPL] and discussed work on Oldoinyo Lengai natrocarbonatite eruptions in east Africa. This unusual volcano had an explosive event, nicely captured by ASTER, which Vaughn has characterized.

**D. Pieri** [JPL] provided an update on the ASTER Volcano Archive project at JPL. The on-line web interface provides full scale JPEGs, links to the Smithsonian Catalog, and draping over *GoogleEarth*.

**Ecosystems/Oceans Working Group**

**G. Geller** [JPL] reported that since June five new STARS were submitted through the Ecosystems Working group.

**Y. Yamaguchi** [Nagoya University] reported on preliminary results of regional evapotranspiration estimates for Nagoya, Japan, using a two-source model with ASTER and meteorological data as inputs. Results met the goal of less than 50 W/m$^2$ error compared with flux tower measurements and the plan is to apply this method to agricultural areas in Nepal in the future[1].

**S. Scheidt** [University of Pittsburgh] provided an update on work focusing on the relationships between sand transport pathways and dust emission hot spots in the Sahara Desert.

**T. Matsunaga** [National Institute for Environmental Studies] reported for **G. Saito** [Tohoku U.] on results of analyses that Saito's group conducted of several upland farming regions. The results demonstrated that upland farming areas can be characterized in terms of topography, area, and shape of farmland.

**Matsunaga** reported for **Y. Sakuno** [Hiroshima University] on his recent study on eelgrass habitat mapping using ASTER data. More efforts will be necessary to validate maps derived from ASTER.

[1] See page 4 of the July-August 2007 issue of *the Earth Observer* for background on this research.

**A. French** [U.S. Department of Agriculture (USDA)] presented methodology and results from combining MODIS and Geostationary Operational Environmental Satellites (GOES) land surface temperature into 1-km, half-hourly datasets over the Southwest U.S.

**H. Yamamoto** [AIST] presented an inter-comparison of in-house ASTER/MODIS surface reflectance products using 6S radiative transfer code, aeronet, and ASTER/MODIS surface reflectance. This experiment expanded on previous research that had shown significant differences between ASTER and MODIS surface reflectance products. Yamamoto explained that the Global Earth Observation (GEO) Grid is an E-Infrastructure designed to accelerate GEO sciences and described the system they developed for applying radiometric re-calibration coefficients and Rayleigh/ozone/water vapor corrected reflectance without aerosol correction. This research enables the intercomparison between ASTER and MODIS top-of-atmosphere radiance, top-of-atmosphere reflectance, and Rayleigh/ozone/water vapor corrected reflectance.

**L. Preshad** [Arizona State University] summarized the *100 Cities Project*, which focuses on studying urban heat islands. The Project includes the United Nation's International Human Development Program, the Chinese Academy of Sciences, the Chinese Ministry of Land and Resources, U.S. Center for Disease Control, and U.S. Environmental Protection Agency. A *Google Earth* mapserver tool is being developed to facilitate getting ASTER-derived surface temperature scenes, vegetation indices, and land cover classifications for the 100 cities to urban practitioners and researchers.

**Matsunaga** reported for **T. Ishiyama** [Chiba University] on 40-year changes in land cover/vegetation around oases in the Taklimakan Desert using Corona, Landsat, and ASTER data. Long-term increases in cotton field extent and recent increases in saline deposits were indicated.

**T. Gubbels** [Science Systems and Applications, Inc.] explained **J. Masek's** (GSFC) and his work on assessing forest cover change and disturbance between 2000 and 2005 using Landsat Geocover and ASTER. Gubbels also reported on **M. Pritchard's** work on snow melt, ice dynamics, and mass balance for Patagonian ice fields.

**Geller** provided an update on the *TerraLook* project, which makes recent ASTER and historical Landsat data available at no cost to non-technical users. He also summarized the plans for the Group on Earth Observations (GEO) Biodiversity Observation Network, which will use ASTER as one of its many data sources.

**Atmospheric Correction Working Group**

**Thome** led a discussion on how best to inform users of saturation of SWIR data. Participants discussed the impact that changing file names or data values would have on end users and decided against making these changes.. They decided to keep the data products the same, and warn users via web-based alerts.

**Eng** went over the status of atmospheric correction software. The next version of the software (*Version 3.2*) is in process of predelivery testing. The newest version removes artifacts at boundaries of inputs; updates ozone sources; and makes available MODIS profile information.

**Yamamoto** presented capabilities of the GEO Grid system (available to Science Team members). The site will allow interactive change of processing parameters, and has available different atmospheric correction algorithms.

**Mars** described his evaluation of SWIR cross-talk corrected data, comparing the ASTER standard *AST07XT* product, and a product he himself developed. Discrepancies between the two products seem to indicate a problem with Band 9 water vapor factors in the standard product, and a reflectance-dependent error in Band 5.

**Radiometric Calibration Working Group**

**S. Tsuchida** [AIST] showed team members how to access the GEO Grid processing system for custom production of higher level products, including different kinds of atmospheric corrections.

**Thome** reported finding no significant temporal trends in Visible/Near Infrared (VNIR) or SWIR data over the past four years. A new web site is in place to convert ASTER values to Landsat Enhanced Thematic Mapper Plus (ETM+) equivalent results. Ground-monitor results are showing promise for providing accurate calibration results using automatic stations.

**Tonooka** showed his web site for recalibration of TIR data. The site continues to operate nominally, and provides users with a simple way to obtain the most accurate calibration coefficients.

**A. Kamei** [AIST] and **Tsuchida** reported on 2007 field campaigns to validate VNIR and SWIR data. They showed results based on *6S* radiative transfer code, and discussed differences with standard methods.

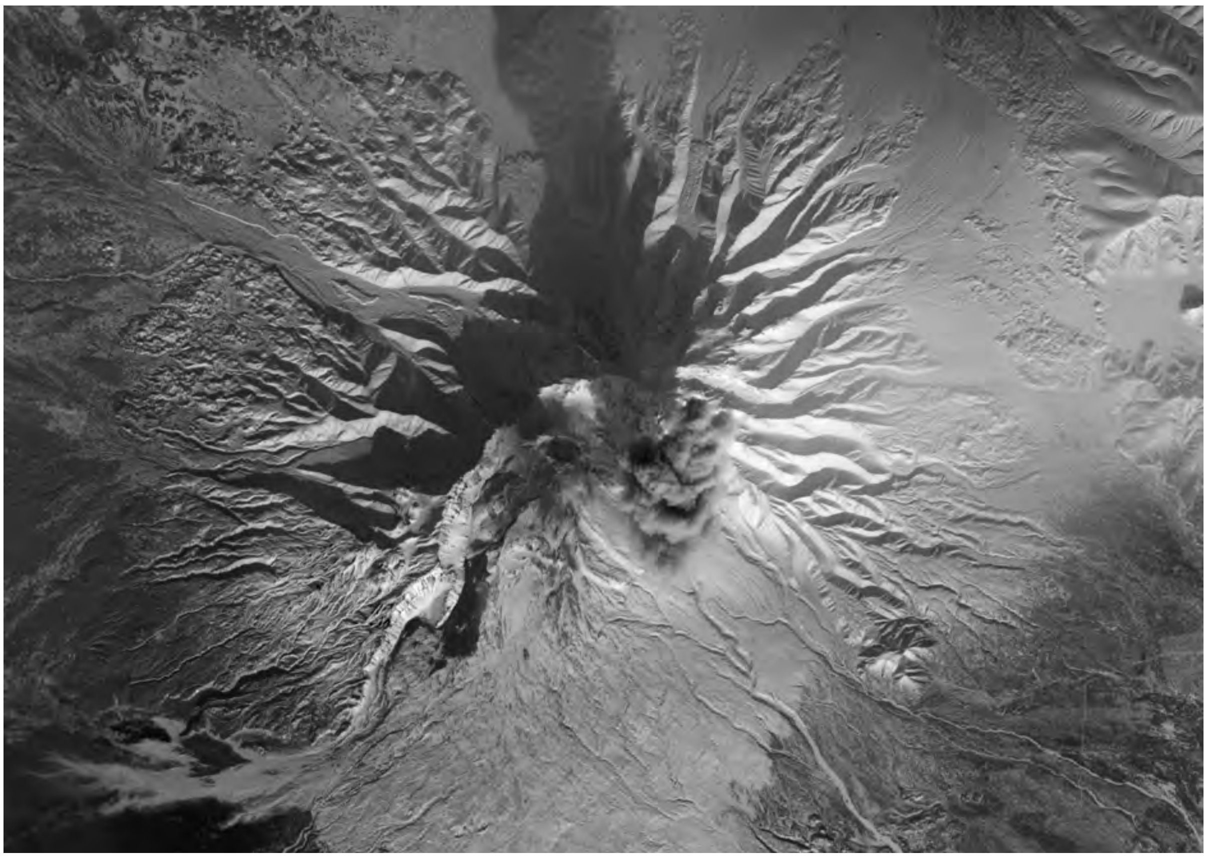
**Sato** showed that the SWIR onboard calibration lamps were saturated due to the increased offset, so they could not be used to evaluate sensitivity coefficient values.

**Closing Plenary Session**

During the final gathering, each Working Group chairperson presented a summary of the discussions and talks that were given during the Working Group session.

With most of the ASTER instrument and related systems working flawlessly, it is not surprising that much of the meeting addressed the sickly SWIR system and how to minimize effects of its problems. Suggested actions include changing to *Low2* gain while allowing the values to be what they will and notifying users by web-based alert. Some products may eventually be eliminated. Other topics of most interest were how to allocate the allowable resources and complete Global Map 3, Global DEM, Nighttime TIR Map, and Gap Filler Map while fulfilling other demands on the instrument.

Overall, the group felt that the instrument and systems are performing extremely well, and look forward to the next ASTER Science Team Meeting to be held in Tokyo, Japan in the second week of June 2008.



On Sunday morning, February 17, 2008, the skies above Shiveluch Volcano in Russia's Far East were clear and calm. When the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite passed overhead, it caught this view of a column of ash from a recent eruption seemingly frozen in the air over the mountain. The southern slopes of the snow-covered volcano were dark with ash. The the ash column rises over the volcano to the east (right) of the active caldera. The shadow of the ash column looms over the northern flank of the volcano. Shiveluch (sometimes spelled Sheveluch) is among the largest and most active of the dozens of volcanoes that sit on the Kamchatka Peninsula in Russia's Far East. **Credit:** NASA's Earth Observatory.

# Ocean Vector Wind Science Team Meeting Report

*W. Timothy Liu, Jet Propulsion Laboratory, California Institute of Technology, liu@pacific.jpl.nasa.gov*

The NASA Ocean Vector Wind Science Team (OVWST) recently held a joint meeting with the European Organization for the Exploitation of Meteorological Satellites' (EUMETSAT) Advanced Scatterometer Science Advisory Group (SAG). The meeting took place in conjunction with the 15th American Meteorological Society (AMS) Satellite Meteorology & Oceanography Conference and the 2007 EUMETSAT Meteorological Satellite Conference in Amsterdam, the Netherlands, September 24-29, 2007.

**Scatterometry Presentations and Posters at the AMS/ EUMETSAT Meeting**

Several keynote presentations in the Oceanography Session of the conference on September 25-26 were related to scatterometer missions.

- **Stan Wilson** [National Oceanice and Atmospheric Administration (NOAA)] reported on NOAA operational applications for scatterometry.
- **Timothy Liu** [Jet Propulsion Laboratory (JPL)] spoke on ocean-atmosphere momentum coupling and potential synergism of international scatterometer missions.
- **Jeroen Verspeed** [Koninklijk Nederlands Meteorologisch Instituut (KNMI)] discussed Advanced Scatterometer (ASCAT) validation.
- **Dudley Chelton** [Oregon State University (OSU)] presented on sea surface temperature (SST) influence on winds.

There were also many oral and poster papers on application of scatterometer measurements.

- **Klaus Scipal** [Vienna University of Technology (TU Wien)] spoke on assimilation of scatterometer soil moisture.
- **Zoltan Bartalis** [TU Wien] discussed soil moisture retrieval using ASCAT.
- **Daniel Esteban Fernandez** [JPL] reported on C-band high incidence scatterometry.
- **Tong Lee** [JPL] reported on the Pacific ocean decadal variability.
- **Fanny Girard-Ardhuin** [Institut Francais de Recherche Pour L'exploitation de la Mer (IFREMER)] reported on sea ice monitoring.
- **Joseph Siekiewicz** [NOAA] discussed extra tropical cyclone detection.
- **Marcos Portabella** [KNMI] reported on high-resolution gridded ocean forcing.
- **Bryan Stiles** [JPL] spoke about retrieving coastal winds.
- **Craig Anderson** [EUMETSAT] discussed calibration of ASCAT backscatter.
- **Zorana Jelenak** [NOAA] discussed airborne observations and modeling.
- **Scott Dunbar** [JPL] spoke on ASCAT and QuikSCAT wind cross-validation.
- **Gene Legg** [NOAA] discussed ASCAT near-real-time data processing and distribution.
- **Timothy Mavor** [NOAA] presented on short-term variability of QuikSCAT wind fields and satellite-derived SST fronts.
- **Anton Verhoef** [KNMI] reported on scatterometer wind services at KNMI.
- **Paul Chang** [NOAA] discussed the NOAA ASCAT near real-time wind data product.
- **Hans Hersbach** [European Center for Medium-range Weather Forecast (ECMWF)] presented an assessment of the equality of the European Remote Sensing (ERS)-1 and ERS-2 scatterometer winds.

**Highlights of the Joint OVWST/SAG Meeting**

**Hans Bonekemp** [EUMETSAT] and **Timothy Liu** [JPL] opened the Joint OVWST/SAG meeting on September 28, 2007. The first day was devoted to presentation of research and operational applications.

The presenters in the first session on storms included:

- **Kathryn Kelly** [University of Washington (UW)] on storm intensification;
- **Yves Quilfen** [IFREMER] on wind retrieval under severe conditions;
- **Mark Leidner** [Atmospheric and Environment Research] on hurricane forecasting;
- **Shuyi Chen** [University of Miami (UM)] on assimilation of scatterometer wind in a high-resolution hurricane model; and
- **Chris Hennon** [University of North Carolina (UNC)] on evaluation of hurricane winds.

Presenters during the second session on climate applications included:

- **Shang-Ping Xie** [University of Hawaii] on mapping high sea winds;
- **Tong Lee** [JPL] on linking variability of meridional circulation in the Pacific and Indian oceans;
- **Frank Wentz** [Remote Sensing System] on the hydrological cycle on decadal time scales;
- **Weiqing Han** [University of Colorado] on intraseasonal changes in equatorial Atlantic;

- **Rong Fu** [Georgia Institute of Technology] on the influence of the Amazon rainfall on El Niño wind anomalies; and
- **Lisan Yu** [Woods Hole Oceanography Institution (WHOI)] on climate variability of ocean surface wind.

Poster presenters included:

- **Mark Bourassa** [Florida State University] on scatterometer model function applicable to varying sea states;
- **Christopher Hennon** [UNC] on tropical cyclone wind vector verification;
- **Timothy Liu** [JPL] on persistent imprints of mid-latitude ocean fronts high into the atmosphere;
- **Fabrice Bonjean** [Earth and Space Research] on real-time ocean surface current;
- **Absornsuda Siripong** [Chulalongkorn University] on wind changes in the South China Sea and ecological impact;
- **Kelly Perry** [JPL] on the Physical Oceanography Distributed Active Archive Center (PODAAC);
- **Claire Perigaud** [JPL] on using QuikSCAT wind stress to understand climate fluctuation in the tropics;
- **Ralph Foster** [University of Washington (UW)] on nonlinear similarity boundary layer models of ocean vector wind;
- **Jerone Patoux** [UW] on scaterometer-derived oceanic surface pressure fields;
- **Ralph Milliff** [Colorado Research Association] on climatological impacts of resolving wind stress curl in hurricanes; and
- **Brian Mapes** [UM] on mesoscale convective systems.

In the third session **Hans Hersbach** [ECMWF], **Simon Keogh** [United Kingdom Meteorological Office], **Paul Chang** [NOAA], **Ad Soffenen** [KNMI], and **Herushisa Simoda** [Japanese Aerospace Exploration Agency (JAXA)] discussed operational applications of scatterometer winds at ECMWF, United Kingdom Meteorological Office (UKMO), NOAA, KNMI, and the Japanese Meteorological Agency respectively.

The fourth session on validation and algorithm development included several presentations of interest.

- **Naoto Ebuchi** [University of Hokaido] talked about evaluation of reprocessed SeaWinds data.
- **David Long** [Brigham Young University] discussed land-contamination detection and correction for wind retrieval.
- **Stephen Frasier** [University of Massachusetts] presented on airborne experiments.
- **David Weissman** [Hofstra University] discussed the impact of rain on scatterometer radar cross sections.
- **Michael Caruso** [WHOI] discussed intercomparison of QuikSCAT, WindSat, and ASCAT retrievals.

The second day (September 29) began with programmatic debriefings by **Eric Lindstrom** [NASA], **Helge Rebhan** [EUMETSAT], and **Stan Wilson** [NOAA].

A session on data processing and products followed, with **A. Chiara** [European Space Agency (ESA)] discussing ERS, **Julia Figa** [ESA] discussing ASCAT, **Ad Stoffelen** [KMNI] discussing the Ocean Sea Ice Satellite Application Facility, and **Zorana Jelenak** [NOAA], and **Ralph Foster** [UW] discussing QuikSCAT.

**Ernesto Rodriguez** [JPL] presented the plan for a U.S. new ocean vector wind mission—a dual-frequency synthetic aperture radar with azimuth diversity that would meet operational hurricane monitoring and forecast requirements. Rodriguez also summarized science studies he has contracted to demonstrate the science capability of the new sensor.

There were also three other talks discussing scatterometer missions.

- **Ad Stoffenen** [KMNI] outlined potential improvement of ASCAT in the future.
- **Hans Bonekemp** [EUMETSAT] presented the plans for a Joint European and China mission of scatterometer and synthetic aperture radar called Chinese–French Oceanography Satellite (CFOSAT).
- **Timothy Liu** [JPL] outlined the characteristics of the scatterometer missions by China and India.

The meeting ended with a discussion on future scatterometer missions. The discussion pointed out that not all space-based ocean surface wind measurements are comparable in quality. A report summarizing the technology requirements for observation accuracies of different research and operational applications is very desirable. The OVWST, the world's most advanced and experienced international group on measuring surface wind vectors from satellites, would be an appropriate group to lead and accomplish the task.

Despite the large difference between the nature of OVWST, which conducts open science team meetings, and SAG which is a closed advisory group with formal purview on its meetings, the joint meeting in Amsterdam went forth as planned, facilitating cooperation across the Atlantic. The need of a high quality, continuous, and consistent long time series for ocean surface vector winds and international cooperation was affirmed. ■

# Public Release of CALIPSO Data Products (Release 2)

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite mission is pleased to announce the initial release of the Cloud-Aerosol LIdar with Orthogonal Polarization (CALIOP) *Version 2* data set. This new release includes changes to the Level-1 lidar calibration, improvements to the aerosol and cloud feature mask, the addition of aerosol subtyping and cloud ice-water phase discrimination, and a 'beta' version of the extinction profile products. The CALIPSO measurements provide new insight into the role that clouds and atmospheric aerosols play in regulating Earth's weather, climate, and air quality. CALIPSO is a joint mission between NASA and Centre National d'Etudes spatiales (CNES) and orbits in formation with four other Earth observing satellite missions in the afternoon satellite constellation (A-Train).

CALIPSO's payload includes a two-wavelength polarization-sensitive lidar (CALIOP), a three-channel passive Infrared Imaging Radiometer (IIR), and a visible Wide Field Camera (WFC). Together, this suite of active and passive sensors probes the vertical structure, spatial distribution and optical properties of thin clouds and aerosols over the globe. The payload has been operational since June 2006. CALIPSO data are being processed and archived by the Atmospheric Science Data Center (ASDC) at NASA Langley Research Center.

To access the released data by using the data ordering tools, visit the ASDC web site: *eosweb.larc.nasa.gov/PRODOCS/calipso/table_calipso.html.*

The Data Quality Summary document, software reader tools, the Data Products Catalogue, related links, and other project documentation and tools are also available at the ASDC CALIPSO page given above.

For more information about CALIPSO, visit: *www-calipso.larc.nasa.gov*

If you have any questions concerning the ordering process, contact the ASDC by email at *larc@eos.nasa.gov.*

This release includes a revision of the Level-1 and Level-2 data set for 2006. Data for 2007 are being reprocessed and will be available in early 2008. Additional data for 2008 will be made available as they are processed. An initial release of the CALIPSO IIR Level-2 data set is also planned in the coming months.

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

NASA Langley Atmospheric Science Data Center
User and Data Services
Mail Stop 157D, 2 S. Wright Street
Hampton, VA 23681-2199

Phone: 757-864-8656
E-mail: *larc@eos.nasa.gov*
URL: eosweb.larc.nasa.gov

# SORCE 5-Year Anniversary Science Team Meeting

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*Approximately 75 scientists gathered for the 5th SORCE Science Team Meeting,* ***SORCE's Past, Present, and Future Role in Earth Science Research****, and to celebrate SORCE's fifth year in-orbit. The group, which met February 5-7 at La Posada Resort in Santa Fe, NM, engaged in stimulating discussions covering a wide range of current solar and Earth Science research.* A summary of the meeting, including PDF versions of the many excellent presentations, is available at: *lasp.colorado.edu/sorce/news/2008ScienceMeeting/.*

**Introduction and Meeting Overview**

A fundamental and challenging component of Earth Science is the proper attribution of observed climate change to variations in solar radiative output. Since its launch in 2003, the SOlar Radiation and Climate Experiment (SORCE) has measured solar irradiance at the top of the Earth's atmosphere with unprecedented accuracy, precision, and (for the first time) spectral coverage across the ultraviolet (UV), visible, and near-infrared (IR) regions of the spectrum. The SORCE Science Team Meetings are convened to both highlight SORCE's unique, state-of-the-art emerging solar irradiance database and to engage the broad scientific community in interdisciplinary scientific issues involving solar irradiance variability and its influence on climate and the Earth's atmosphere on multiple time scales.

The primary focus of the 2008 Science Team Meeting was utilization of improved solar irradiance measurements and models, such as being developed by SORCE, to help advance climate and atmospheric models, in conjunction with ongoing Earth Science measurements. Included were presentations and discussions of solar variability measurements, models and predictions and the modeled and measured response to this variability of Earth's atmosphere and climate. Of particular interest were models that incorporate the physical processes thought to facilitate the Sun-Earth connection. Coupled with accurate solar and climate measurements, these models are critical in determining and understanding climate sensitivities to solar forcing. Key questions motivating the meeting agenda were:

- *What is the present state of knowledge of the total solar irradiance (TSI) and solar spectral irradiance (SSI) in the ultraviolet, visible, and near infrared spectral ranges?*
- *How have the key radiative, photochemical and dynamical processes affecting Earth's atmosphere and ozone, changed over the past few decades, in comparison with other influences?*
- *How much of the stratospheric heating by the solar ultraviolet radiation couples to the lower atmosphere and surface?*
- *How do the water cycle and cloud coverage respond to solar forcing, and how do these processes affect the long-term climate?*
- *How can drivers in the Sun causing solar cycle variations be better quantified to estimate past and future solar irradiance changes, such as in times like the Maunder Minimum?*

Previous meetings have addressed equally stimulating and topical aspects of the Sun-climate connection, including:

- *Physical Processes Linking Solar Radiation and Solar Variability with Global Climate Change (Sonoma, CA, 2003)*
- *Decadal Variability in the Sun and Climate (Meredith, NH, 2004)*
- *Paleo Connections Between the Sun, Climate, and Culture (Durango, CO, 2005)*
- *The Earth's Radiative Energy Budget Related to SORCE (San Juan Islands, WA, 2006)*

Summaries of prior meetings can be found at: *lasp.colorado.edu/sorce/meetings.html.*

**Session 1: Variability of the Solar Irradiance Over the Solar Cycle**

The meeting's first session reviewed total and spectral irradiance variations over the 11-year solar cycle and discussed potential causes and indicators of this variability. SORCE's original Principal Investigator (PI), **Gary Rottman** [Laboratory for Atmospheric and Space Physics (LASP), University of Colorado (CU)—Boulder, CO], chaired the session and introduced the current PI and first speaker, **Tom Woods** [LASP, CU]. Woods' talk, *What we've learned from SORCE,* presented an overview of the extensive new observations of both total and spectral irradiance that the SORCE mission is making in *solar cycle 23*. Now that SORCE has completed five years of observations spanning solar maximum-like activity levels to the current solar minimum—**Figure 1**—the team eagerly anticipates tracking the upcoming *cycle 24*, which (as the attendees heard the following day) may be larger (or not?) than cycle 23. Woods highlighted some of the major findings—and new questions—from SORCE, including how changes at different wavelengths in the spectrum can relate differently to solar activity and total irradiance—**Figure 2**—and to each other, on different time scales. With the completion of its primary mission, SORCE now embarks upon its approved extended mission to 2012.

With the focus of this SORCE Science Meeting on utilization of solar irradiance knowledge by Earth Science research, **Judith Lean** [Naval Research Laboratory—Washington, DC] showed how models of irradiance variability across the entire spectrum were developed (before SORCE) for use in a range of climate and atmospheric simulations. She compared these models with SORCE observations, and identified recent improvements and modifications based on the short-term SORCE/Solar Irradiance Monitor (SIM) and Solar Stellar Irradiance Comparison Experiment (SOLSTICE) spectral irradiance measurements. Such models are used as input to general circulation models discussed later in the meeting by David Rind, and atmospheric

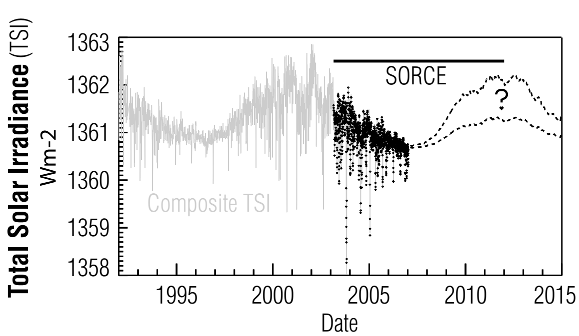



**Figure 1.** A time series based on the SORCE TIM TSI extending back to 1992. The black symbols correspond to TIM measurements during the period of the SORCE mission and the dashed line demonstrates the range of value estimated for the next solar cycle. With the extended mission, SORCE could potentially operate to 2012. **Credit:** T. Woods.

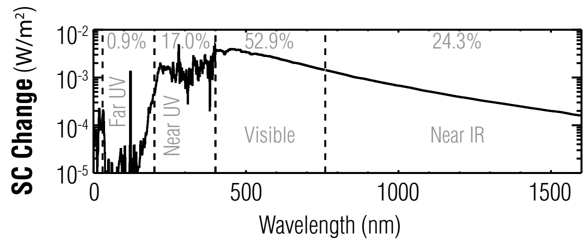



**Figure 2.** Variations in radiant energy during the solar cycle can be attributed to different wavelength regions based on SORCE spectral solar irradiance observations. **Credit:** T. Woods.

chemistry models, discussed later by David Lary. Lean also showed that two-component (sunspot and faculae) models fit the SORCE/Total Irradiance Monitor (TIM) data better than those from any other TSI instrument because of the TIM's low noise.

**Greg Kopp** [LASP, CU] broadened the scope of the meeting beyond SORCE in his talk *The History and Future of TSI and SSI Measurements*, summarizing the database of spacecraft measurements contributing to the total and spectral solar irradiance records. In particular, Kopp discussed the desired accuracies and instrument stabilities needed to detect elusive long-term changes in the Sun in both TSI and SSI. This set the background for several instrument- and data-specific irradiance talks that followed. The solar irradiance community eagerly anticipates the upcoming Solar Spectrum Measurement (SOLSPEC) spectral solar irradiance observations spanning 165–3080 nm from the SOLAR instrument suite, which **Gérard Thuillier** [Service d'Aéronomie du CNRS (Centre national de la recherché scientifique)—France] described.[1]

Continuing an ongoing topic of all SORCE meetings—the multi-decadal variability of total irradiance—**Steven Dewitte** [Royal Meteorological Institute of Belgium] and **Claus Fröhlich** [Physikalisch-Meteorologisches Observatorium—Davos, Switzerland] gave consecutive talks on their latest creations of TSI composites based on data from the Solar and Heliospheric Observatory (SOHO) and other TSI instruments. Because of different assumptions about extant data records, their conclusions were somewhat conflicting; Dewitte's reconstruction did not support Fröhlich's finding of an overall irradiance decline in the current solar minimum. Fröhlich also discussed the methods by which the TSI record can be extended back in time via proxies. Reliable irradiance reconstructions require improved understanding of the source of the irradiance variations, which **Gary Chapman** [San Fernando Observatory, California State University] demonstrated with impressive fits to TSI data using ground-based observations—**Figure 3**.

[1] In an exciting "real-time" addendum, SOLAR was successfully launched on Space Shuttle Columbia on the last day of the SORCE meeting.

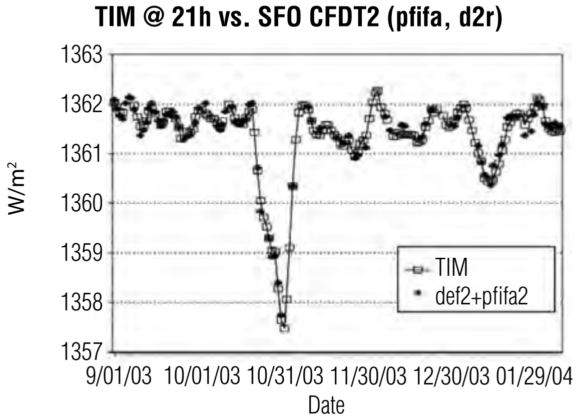



**Figure 3.** Gary Chapman's group at San Fernando Observatory showed impressive fits to TSI measurements during the very active October 2003 time period. **Credit:** G. Chapman.

**Alexander Ruzmaikin** [NASA/Jet Propulsion Laboratory—Pasadena, CA] applied a *mode decomposition* method to both the SORCE/TIM TSI data and to historical TSI proxy records to determine the dominant solar variability modes.

Spectral irradiance variations are not nearly as well specified as the total irradiance. To help rectify this, work is underway by **Matt DeLand** [Science Systems and Applications Inc.—Lanham, MD] to create composite records of spectral solar irradiance over the wavelength range 120–400 nm. Deland showed preliminary results for solar records going back 30 years. A pioneer of spectral irradiance variability theory, astrophysicist **Yvonne Unruh** [Imperial College—London] discussed the application of the Spectral And Total Irradiance REconstructions (SATIRE) models to SORCE total and spectral irradiance measurements during the May-July 2004 time period. SATIRE, which utilizes knowledge of the spectral character of solar magnetic fields identified in solar imagery, shows good fits from 220–1600 nm. Unruh suggested the model perhaps estimates the spectral solar irradiances with better accuracy than does the instrument record from 310–350 nm.

**Doug Biesecker** [NOAA, Space Weather Prediction Center—Boulder, CO] ended the first session and entertained the attendees with *Predictions of the Solar Cycle, Past and Present,* providing a fascinating synopsis of the challenges which the recent NOAA panel encountered when tasked with predicting the upcoming *solar cycle 24*. Biesecker showed the methods by which such predictions are made and their resulting historical accuracies. A fundamental lack of understanding of the nature and processes of the solar dynamo prevented the panel from making an unequivocal prediction. Rather, they acknowledge the possibility of both high and low levels for the next solar cycle maximum sometime in 2012-2013.

**Session 2: Atmospheric Models, Processes, and Solar Irradiance**

A series of excellent, instructive talks composed this informative session, which explored current atmospheric models and chemical and dynamical processes related to stratospheric and tropospheric chemistry. With **Erik Richard** [LASP, CU] chairing, **Michael King** [NASA Goddard Space Flight Center (GSFC)] commenced the session with *NASA's Earth Observations of the Global Environment: Our Changing Planet and the View from Space* (based on his book by the same name), providing a comprehensive overview, with stunning imagery, of how EOS satellites are documenting contemporary global change. He showed an array of global data including cloud properties, surface and atmospheric temperature, composition and precipitation—**Figure 4**. These data are crucial in understanding the underlying processes related to our changing planet.

*Long-Term Multi-Dataset Analysis* is crucial for Earth Science. **David Lary** [NASA GSFC] presented an excellent discussion of this topic, in which he described innovative techniques for analysis and assimilation of long-term data sets related primarily to atmospheric chemical modeling. This included optimum system design and the unique incorporation of genetic (evolving) algorithms. In cases where data understanding is limited, the use of neural networks provides a powerful framework for enhancing analysis capabilities. The final talk on Tuesday was by **Kiyotaka Shibata** [Meteorological Research Inst. (MRI)—Tsukuba, Japan], about recent work on the temperature and ozone response to solar cycle changes in the tropical stratosphere. In addition to the solar irradiance forcing, Shibata emphasized the importance of the ensemble simulation of a coupled-chemistry-climate model including the forcings of sea surface temperature, sea-ice coverage, greenhouse gases, and volcanic aerosols for conducting this analysis. Over a 25-year period, it was found that

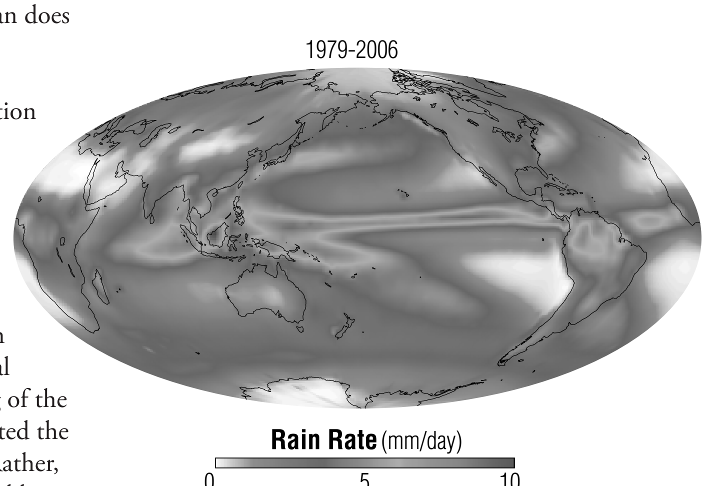



**Figure 4.** Map of the geographical distribution of rain rate over the globe. **Credit:** M. King.

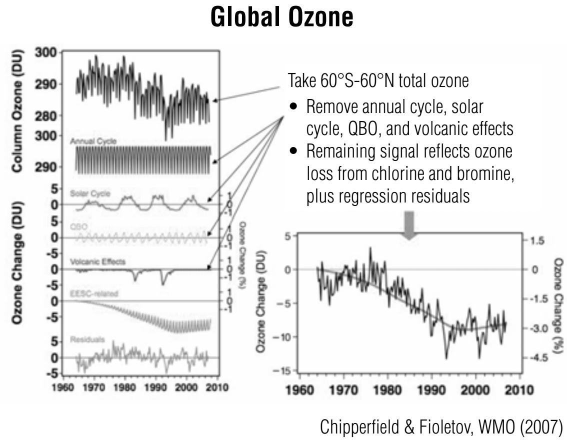



**Figure 5**. Attribution of natural and anthropogenic sources of variation in total global ozone during the past 45 years.
**Credit:** P. Newman.

the annual-mean solar signals reproduced the observed trends in ozone variability in the tropical stratosphere. A chemical effect due primarily to the UV irradiance variability and a dynamical effect resulting from atmospheric transport mechanisms were cited as two key causes of these trends.

Wednesday morning began with the excitement and energy of a keynote talk on *The Aura Mission* given by **Mark Schoeberl** [NASA GSFC]. Meeting attendees were apprised of the latest remarkable information from Aura about atmospheric pollution, long range transport, and lower (tropospheric) and upper (stratospheric) atmospheric exchange. The four instruments on Aura have been providing detailed chemical information and evolution on both global and regional scales. **Paul Newman** [NASA GSFC] continued the theme of atmospheric variability with a fascinating and topical talk about *Estimating When the Antarctic Ozone Hole Will Recover.* He described detailed model estimations (and comparisons) on the time frame for ozone recovery to pre-1980 levels as well as factors that might obscure or modify the recovery projections—**Figure 5**. In addition to solar and other sources of natural variability, such factors include uncertainties in equivalent effective stratospheric chlorine, mean air age, chlorine and bromine budgets and longer term climate effects. Through parametric modeling of ozone hole area with respect to stratospheric temperature a projection curve was generated and was consistent with a recovery onset evident around 2024 with a full recovery by 2067.

**Jay Mace** [University of Utah] discussed cloud microphysics results from the recently launched CloudSat satellite. Mace has done a creative multi-dataset analysis and merged the first year of millimeter radar data collected by CloudSat with lidar data collected by Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) (July 2006-June 2007) to investigate the occurrence statistics of hydrometeor layers covering the Earth's surface. Mace's remarkable high-resolution images demonstrated the vertical and horizontal distribution of cloud occurrence, vertical structure, and layer overlap. Through the collective incorporation of the emerging A-Train data set, understanding the physical processes that couple clouds and precipitation with the large-scale dynamics is now a more tractable problem. In the last talk of Session 2, **Terry Nathan** [University of California, Davis] presented *On the Connection Between Solar Spectral Irradiance, Planetary Wave Drag and the Zonal-Mean Circulation.* He explained how planetary wave drag communicates variations in solar spectral irradiance to longitudinal variations in ozone. He examined this connection using both analytical and numerical models that couple radiation, ozone, and dynamics in the extratropical atmosphere. Ultimately, by incorporating the effects of solar spectral irradiance-induced changes in ozone on planetary wave drag, a more complete pathway for communicating solar cycle induced changes in stratospheric ozone distributions could be identified.

**Session 3: Models of Solar Processes Affecting Climate**

This session provided an overview of current theoretical understanding of the Sun and solar variability, which is ultimately needed to provide a scientific underpinning of observed (and forecast) irradiance variations that force climate change. **Greg Kopp** [LASP, CU] chaired the session, which began with a talk by **Mark Miesch** [High Altitude Observatory, National Center for Atmospheric Research (NCAR)—Boulder, CO] on solar convection and processes causing the solar magnetic activity cycle. Miesch showed beautifully colored, time-dependent, three-dimensional simulations of giant cells, meridional circulation, tachocline instabilities, and the solar dynamo, and discussed their contributions to the solar cycle. Knowledge of the transport of magnetic flux on the Sun is crucial for investigating many problems in solar variability, and for augmenting theoretical dynamo models. **Karel Schrijver** [Lockheed Martin Advanced Technology Center—Palo Alto, CA] presented a highly educational and captivating depiction of *Magnetic Flux Transport Modeling,* describing how recent models that he has developed account for surface flux transport by meridional flow, diffusion and differential rotation—**Figure 6**. Such models permit time-dependent simulations of regions of the open and closed magnetic fields, which dominate, respectively, active regions in the solar atmosphere, and the interplanetary magnetic field. Schrijver's compelling visual presentation and explanations of advanced solar transport concepts (e.g., modulation of meridional flows and their effects on the solar cycle) made the topic easier to understand.

Reconstructions of solar irradiance, which are needed for climate research on time scales that are much longer

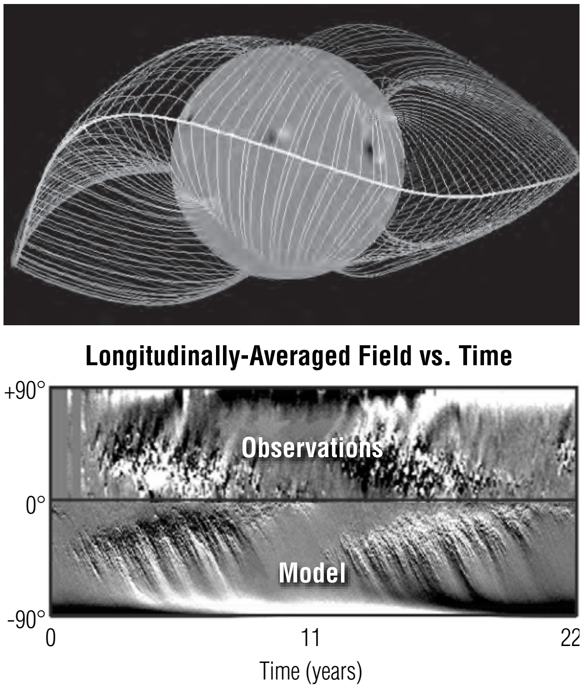



**Figure 6.** Karel Schrijver discussed the transport of magnetic flux on the Sun's surface (bottom), the difference between open and closed magnetic fields from the Sun (top) and their resulting effects at the Earth on irradiance proxies. **Credit:** of K. Schrijver.

than the 30 years of space observations, is a recurring topic of SORCE Meetings. **Sami Solanki** [Max Planck Institute—Lindau, Germany] described *Solar Irradiance and Activity Reconstructions on Timescales up to Millennia*, extending Unruh's SATIRE model, based on short-term solar magnetic variability, to solar cycle and longer time scales. Solanki presented reconstructions of the TSI back through the Maunder Minimum in the late 1600s via direct solar activity observations and then back another 11,000 years via cosmogenic isotopes. Since the cosmogenic isotopes reflect variations in the open magnetic flux (that extend into the heliosphere), whereas the closed magnetic flux produces irradiance vibrations, such reconstructions ultimately relate to how the Sun transports magnetic flux.

Active regions in the Sun's atmosphere were modeled and characterized in the next two talks. **Juan Fontenla** [LASP, CU] explained the sensitivity of SSI to formation heights of spectral line and continuum opacities, and showed the contributions of seven solar activity types to the SORCE/SIM spectral solar irradiance measurements from the near UV to near-IR. Of particular interest are the variations in near-infrared emission at wavelengths between 1000 and 1600 nm, which emerge from lower in the photosphere than the visible radiation. **Mark Rast** [LASP, CU] presented his current work identifying latitudinal solar intensity variations in the beautiful ground-based images from the Precision Solar Photometric Telescope (PSPT) at Mauna Loa Observatory in Hawaii, with the goal of discerning thermal versus magnetic causes of disc-integrated variations.

Injecting humor appropriate for any attempt at solar cycle predictions, **David Hathaway** [NASA Marshall Space Flight Center—Huntsville, AL], treated the meeting attendees to a glimpse of the interior workings of the Sun thought to generate upcoming solar activity. As Yogi Berra noted (Hathaway explained), "prediction is very difficult, especially about the future." His talk *Estimating the next Solar Cycle* described two different flux transport solar dynamo models, one dominated by meridional flow—**Figure 7**—and the other by diffusion, and the resulting very different estimates of the peak of the next solar cycle.

Hathaway's suggestion that observations of other stars could help select between the solar dynamo models, led nicely into **Tom Ayres'** [Center for Astrophysics and Space Astronomy (CASA), CU] whimsical, entertaining, and insightful assessment of *How Star-Like is the Sun: How Solar-Like are the Stars?* A long-term, star gazer and solar-stellar expert, Ayres described current solar-stellar conundrums—**Figure 8**—concluding that the Sun is relatively star-like, although it exhibits slightly low activity levels, and pointed out how the upcoming Kepler mission should greatly improve our knowledge about stellar activity levels. **Jeffrey Hall** [Lowell

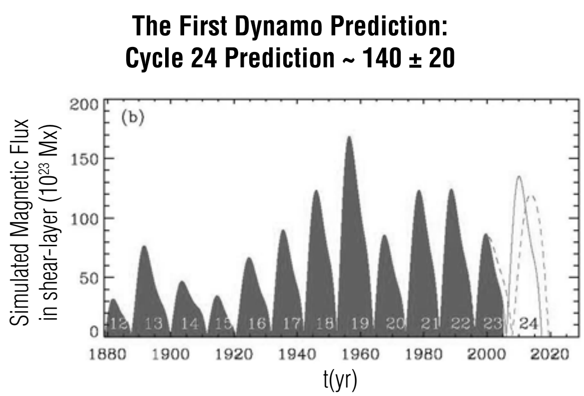



**Figure 7**. A flux transport dynamo with strong meridional flow predicts high solar activity in *cycle 24*. A different dynamo model which emphasizes diffusion over merdional flow in the transport of magnetic flux, predicts smaller activity. **Credit:** D. Hathaway.

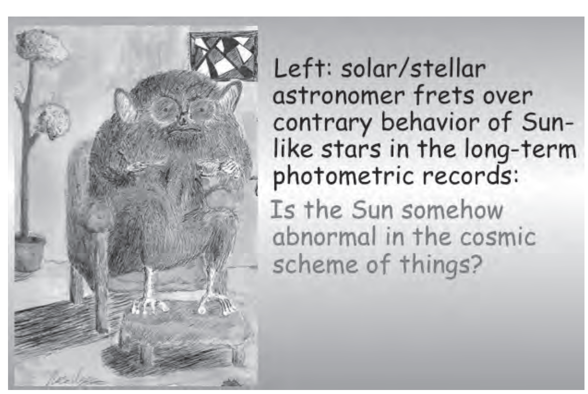



**Figure 8**. There are many ambiguities between solar and stellar photometric records that inhibit reliable determination of the stellar context of solar variability. **Credit:** T. Ayres.

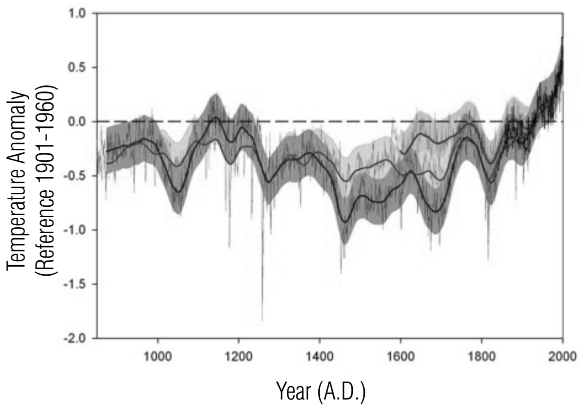



**Figure 9.** Simulations with the National Center for Atmospheric Research's climate model of long-term changes in surface temperature arising from different amplitudes of long-term solar irradiance variations (shown in different shades). None of the assumed solar variations account for the rapid warming since 1960. **Credit:** C. Ammann.

Observatory—Flagstaff, AZ], a veteran of prior SORCE meetings and an authority on Sun-like stars, extended the solar-stellar comparisons to Grand Minima periods, concluding that stars exhibiting extended periods of low activity do not show appreciably less activity than the current Sun during its solar cycle minimum. He further showed that extended ground-based observations have identified some new Sun-like stars, such as 18 Sco.

**Session 4: Climate Models, Processes, and Solar Irradiance**

**Jerry Harder** [LASP] and **Robert Cahalan** [NASA GSFC] chaired the final session of the meeting, which commenced on Wednesday afternoon with **Caspar Ammann's** [NCAR] presentation on the *IPCC Report and Possible Solar Contributions to Climate Change.* Invoking an assortment of model and observational evidence, Ammann explained how recent advances in the available climate records with improved understanding of the climate system have clarified conceptual uncertainties and removed most of the contentious scientific issues that the increase in greenhouse gases is the dominant cause of the ongoing changes in climate. Even using solar irradiance changes significantly larger than what is currently believed to be happening, the recent global surface warming cannot be explained by natural variability—**Figure 9**. Ammann clearly identified the challenges to improve our understanding of the solar forcing contribution and identify systematic solar signals in past climate (time and space) to be used to formulate benchmarks for climate models. Because there is no significant trend in solar forcing over the past 50 years, solar variations cannot explain the warming in recent times. This recent timeframe is dominated by anthropogenic forcing while natural forcings (e.g. increased volcanism) likely contributed a cooling signal. Interestingly, Ammann showed that regional climate change signals, including from solar variability, could be larger than the global changes.

**Robert Cahalan** [NASA GSFC] presented a talk entitled *Modeling the Wavelength and Time Dependence of Solar Forcing of Earth's Atmosphere and Ocean Mixed Layer* in which he discussed the results of a one-dimensional radiative convective model incorporating the solar spectral irradiance variability from the near UV to the near IR as measured by the SORCE SIM instrument. Driving this model with the SIM spectral irradiances produced temperature profiles that differed significantly from the responses to total solar irradiance variability without unique spectral variations.

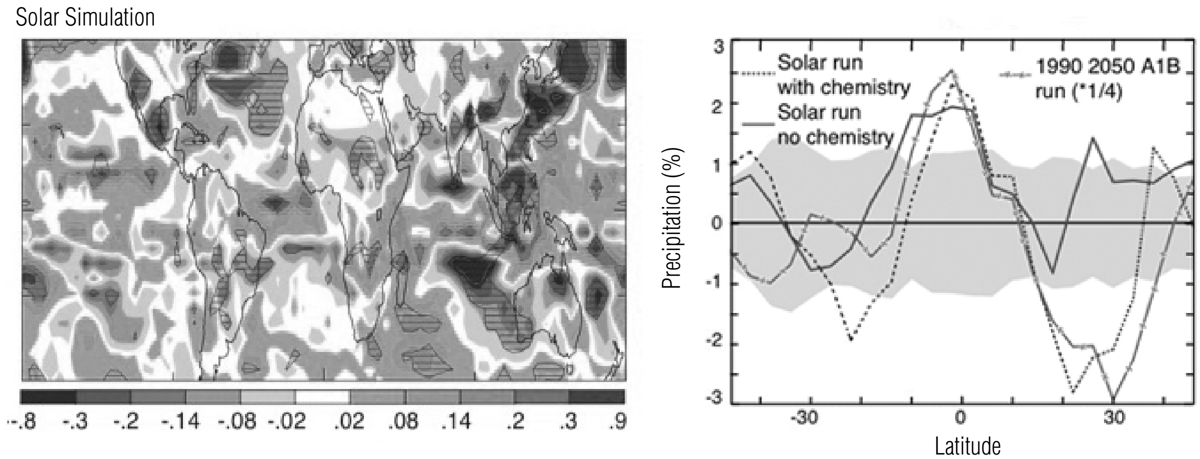
On Wednesday evening the group continued the day's science discussions during a special dinner at *La Casa Sena*, a local Santa Fe favorite in the heart of old town. The warm ambience, delicious northern New Mexican cuisine, and award winning wine list, set the stage for in-depth science debate late into the evening.

**Session 4** continued Thursday morning with a fascinating discussion by **Tom Crowley** [University of Edinburgh—Scotland] of apparent correlations between pulses of volcanism with the Dalton, Maunder, and Sporer Minima—**Figure 10**. In this provocative keynote talk, *Fire vs. Fire: Do Volcanoes or Solar Variability Contribute More to Past Climate Change?* Crowley discussed long-term proxy data showing that refined records of volcanism (as determined from ice core analysis) suggest that episodes of volcanism explain more decadal temperature variance than can be linked to solar variability as identified by cosmogenic isotope variations. In this interesting case of the *correlation vs. causation* argument, Crowley noted that formal statistical detection and attribution studies arrive at the same conclusion. While there is still room for debate, a preliminary message here is that solar variability may be at best marginally significant on multi-decadal to centennial time scales.

Simulations by global general circulation models are key tools for understanding processes that facilitate a climate response to various forcings. In *Exploring*


**Figure 10.** The title slide of Tom Crowley's keynote talk, assessing the relative contributions of solar variability and volcanic activity to climate change in the past millennium using recent, refined estimates of volcanic aerosols. **Credit:** T. Crowley.

**Precipitation Response (Max-Min)**




Notice that:

- Inclusion of tropospheric chemistry increases tropical sensitivity. We see a significant increase in equatorial surface air temperature/precipitation and a decrease in sub-tropics (very similar to greenhouse gas scenarios), and a slowing of the Hadley circulation.
- The Northern Hemisphere Winter signal responds to changes in Arctic Oscillation/North Atlantic Oscillation.

**Figure 11.** Simulations of the change in precipitation from the minimum to maximum of the solar cycle, made with the GISS Model E. **Credit:** G. Schmidt.

*the Tropospheric Response to Solar Forcing,* **David Rind** [NASA Goddard Institute for Space Studies (GISS)—New York] explained how spectrally-differentiated solar radiation changes from 1950-2005 are incorporated into the GISS Global Climate/Middle Atmosphere Model 3. Simulations in which the ocean is not allowed to respond emphasize the solar *stratospheric forcing* of the troposphere, while simulations with the full ocean response illustrate the solar *surface-driving* capability. Rind's findings show that solar cycle effects in the stratosphere are highly significant, and do depend on the ozone profile change; however, the modeled changes account for only a small percentage of variance in the troposphere. **Gavin Schmidt** [NASA GISS] discussed the solar forcing of past-climate proxies in his talk, *Modeling Solar Cycle Impacts on Tropical Hydrology and Proxy Records*. He reported simulations of solar-driven climate change made with the GISS Model E—**Figure 11**—and also addressed what he views as several problems in extracting solar influence signal from paleo-data proxies including issues related to non-climatic noise in data archives and the ubiquity of decadal variability in climate. Because 10–12 year periodic variations do not alone imply solar response there is the likelihood of unclear interpretation of proxies, with particular focus on records of $^{10}Be$ in polar ice cores. He pointed out that because *phase drift* is often ignored (or described as non-linear) explained variance can often be misleading. He cautioned the use of too much correlation, and not enough causation in such interpretation. Schmidt's conclusion: *There's many a slip twixt cup and lip.*

*Climate Forcing Since 1960: What Does the Moon Have to Say?* **Richard Keen** [University of Colorado] proceeded to answer this question with an intriguing and novel depiction of how the Moon may be used to remotely sense global average optical depth—particularly for volcanic stratospheric aerosols, which can affect the observed brightness of the eclipsed Moon. Using the difference between observed and predicted brightness of a lunar eclipse, it is possible to determine the optical thickness of the aerosol layer. Keen showed eclipse data covering time periods of the Pinatubo eruption in 1991 and the Krakatau eruption in 1883. He also showed that presently stratospheric aerosols are near historical background levels. In another talk about novel and innovative techniques, **David Young** [NASA Langley Research Center—Hampton, VA] presented an overview of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Mission. CLARREO was one of the highest priority missions expressed in the National Research Council's (NRC) Earth Science Decadal Survey, and shares several characteristics with SORCE including the need for absolute accuracy, the evolution from total energy measurements to spectral, and long-term continuity. One of the high-level goals of CLARREO is the measurement of long-term trends in key climate variables necessary to improve climate prediction accuracy. Specific measurement needs are the absolute spectrally-resolved measurements of terrestrial thermal emission with an absolute accuracy of 0.1 K in brightness temperature (99% confidence limits) and the absolute spectrally-resolved measurements of the solar radiation reflected from Earth.

**Steve Volz** [NASA Headquarters—Washington, DC] presented the final talk of the meeting, and gave a comprehensive overview of NASA Earth Science new mission concepts for the future. Volz's talk focused on two aspects that can be best described as *where are we now* and *where are we going*? Included in the discussion was a synopsis of missions on orbit (e.g. SORCE, Aqua, Aura, ACRIMSat, the Ice, Clouds and land Elevation Satellite (ICESat), etc.) as well as missions in development, in particular, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP), the Landsat Data Continuity Mission (LDCM), the Orbiting Carbon Observatory (OCO). These missions cover all key scientific focus areas listed as climate variability and change, atmospheric composition, carbon cycle, weather, water and energy cycle, and Earth surface and interior. The run-out for the current NASA Earth Sciences budget reflects an acceleration in the Earth Science Decadal Survey mission queue as well as support for the NRC Decadal Survey priorities. Anticipated are increases in funding for space science research and analysis (R&A) and mission operations and data analysis (MO&DA) activities to get better value from our flight missions, an increase for space science suborbital research programs to foster principal investigator (PI) on-ramps, technology demonstration, and accomplish more science, and an increase in the number of planned missions in all four of the Science Mission Directorate's (SMD's) science theme areas. Volz also identified the two things that primarily influence NASA's strategic planning, namely the NRC Decadal Survey and the NPOESS Nunn-McCurdy Response.

To conclude the productive and enjoyable 5$^{th}$ SORCE Science Meeting, **Tom Woods** [LASP, CU] summarized the excellent presentations and engaging science discussions that had occurred over the 2.5 days. The workshop raised several intriguing questions that the SORCE extended mission may answer.

*What is the long-term trend in TSI observations?* The recent trends at current solar cycle minimum suggest that the solar Modern Maximum period might be on the decline. Continued observations by SORCE TIM and new TSI measurements from NASA Glory, ESA SOLAR, and ESA PICARD are expected to continue the TSI record into *solar cycle 24*.

*What is the solar cycle variation in the near-infrared (NIR)?* The SORCE SIM data yield an inverse relationship with solar cycle that is higher NIR levels during cycle minimum. New validation is anticipated for the SSI measurements with the ESA SOLAR instruments recently installed on ISS.

*How big will solar cycle 24 be?* There are interesting, but conflicting, predictions for both high and low levels for the next maximum in 2012-2013. Time will tell which prediction, if any, is correct.

**Poster Session Presentations**

During the Poster Reception Tuesday afternoon, attendees had an opportunity to peruse the contributed posters while enjoying drinks, appetizers and social interactions. Posters included:

**Douglas Allen, Dordt College, Sioux City, IA**
*Using SORCE Data in the College Classroom*

**Gary Chapman (Angie Cookson), San Fernando Observatory, California State University**
*TSI and Ground-Based Data: What Can be Learned?*

**Jerry Harder, LASP, University of Colorado**
*Spectral Decomposition of the TSI Record Using the SORCE TIM and SIM Instruments*

**Dora Preminger, San Fernando Observatory, California State University**
*The Relationship between Sunspots and the Variability of the Solar Corona*

**Martin Snow, LASP, University of Colorado**
*Ultraviolet SSI Variability from two SOLSTICEs*

**Rodney Viereck, Space Weather Prediction Center, NOAA, Boulder, CO**
*Solar EUV Observations from the NOAA GOES 13 Satellite*

**Tom Woods, LASP, University of Colorado**
*XUV Photometer System (XPS): Improved Solar Irradiance Algorithm Using CHIANTI Spectral Models*

**Erik Richard, LASP, University of Colorado**
*Solar Spectral Irradiance Variability in the Near-Infrared and Correlations to the Variability of Total Solar Irradiance during the Declining Phase of Solar Cycle 23*

**David Harber, LASP, University of Colorado**
*Absolute Optical Power and Irradiance Comparisons with SORCE/TIM and Glory/TIM Instruments*

**Doug Lindholm, LASP, University of Colorado**
*SORCE Solar Irradiance Data Products*

**Christopher Pankratz, LASP, University of Colorado**
*LASP Interactive Solar Irradiance Datacenter (LISIRD)*

**Jae N. Lee, Stony Brook University, NY**
*The Role of Solar Forcing in the Tropical Circulation*

**Rock Bush, Stanford University, CA**
*Michelson Doppler Imager Observations of the Solar Radius over Cycle 23*

**Leif Svalgaard, ETK, Houston, TX**
*Reconstructing TSI from Heliospheric Magnetic Field as Deduced by McCracken from Cosmic Ray Modulation*

**Sheila Lynch, Northeast Advanced Vehicle Consortium, Boston, MA**
*Applying Relativity to Earth Climate Data: The Damhsa Theory Signs of the Inflationary Universe*

**Guoyong Wen, NASA GSFC and University of Maryland, Baltimore County (UMBC)**
*Modeling Lunar Borehole Temperature in Order to Reconstruct Historical TSI and Estimate Surface Temperature in Permanently Shadowed Regions*

The SORCE team extends a hearty thanks to all participants for making the 5th Science Team Meeting so enjoyable, and such a success (even if it was cold in Santa Fe). Future plans are to meet next in Montreal, Canada, as part of the International Association of Meteorology and Atmospheric Sciences (IAMAS) Symposia, July 19-29, 2009. SORCE will participate in a special 3-day session titled *The Impact of Solar Variability on Earth* during the second week of the conference. The session will address all aspects of the impact of solar variations on the Earth's climate, atmosphere, and oceans. As new information becomes available, it will be posted to the SORCE Science Meetings website: *lasp.colorado.edu/sorce/meetings.html.*

# 2007 Lille A-Train Symposium Summary

*David Winker, NASA, Langley Research Center, David.M.Winker@nasa.gov*
*Jennifer Collings, NASA, Langley Research Center, Jennifer.D.Collings@nasa.gov*

The 2007 A-Train Symposium, titled *Bringing together A-Train observations and modeling to understand aerosol and clouds* was held October 22-25, 2007 at the Lille Grand Palais in Lille, France. The four-day symposium was co-organized by Centre National d'Etudes Spatiales (CNES), Institut National des Sciences de l'Univers/Centre National de la Recherche Scientifique (INSU/CNRS), Lille University, and Région Nord-Pas-de-Calais and was a combination of plenary sessions and poster sessions.

The Afternoon or "A-Train" satellite constellation currently consists of five Earth observing satellites that fly in formation as they orbit the Earth. NASA's Aqua, Aura, and CloudSat satellites, the joint NASA–CNES Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite, and CNES' Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL) satellite make up the A-train. Soon, NASA's Glory and Orbiting Carbon Observatory (OCO) satellites will join the constellation. Several of the A-train satellites carry instruments to measure aerosols and clouds, and by flying in formation allow observations from multiple instruments to be combined and compared, offering new perspectives.

This four-day event sought to provide an opportunity for researchers to discuss and analyze the *synergy* of the data from the various A-Train satellites and the influence of aerosols and clouds on the Earth's radiation budget and climate. Discussion topics included observations of the upper troposphere and lower stratosphere, as well as modeling of climate and air quality.

After a welcome cocktail and a congress dinner, the symposium continued with a series of sessions in which researchers shared their findings. Sessions were organized on remote sensing of aerosols and clouds; modeling of aerosols and clouds; and interactions of aerosols, clouds, radiation and precipitation. There were nearly 40 oral talks and more than 100 poster presentations.

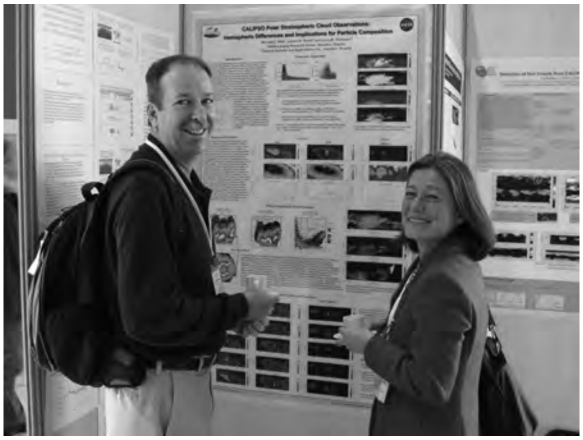
The symposium provided a new and exciting opportunity for A-Train scientists to compare data from the two newest members of the constellation: CALIPSO and CloudSat. Using active techniques, CloudSat and CALIPSO provide direct measurements of cloud height and of multilayer cloud structures that are being used to assess and improve passive cloud retrieval techniques. Several researchers presented comparisons of cloud observations from CloudSat and CALIPSO with those from passive sensors.

**Jay Mace** [University of Utah, Salt Lake City] presented the first global cloud statistics produced by merging radar and lidar profiles from CloudSat and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)—a.k.a., the CALIPSO lidar. The CloudSat 95 GHz Cloud Profiling Radar is able to penetrate to the base of even deep convective clouds while CALIOP observes optically thin clouds and has high vertical resolution to measure clouds very near the surface. This merged dataset provides the first three-dimensional global cloud dataset which resolves cloud structure from the tropopause all the way to cloud base and provides a benchmark against which to test a wide range of models.

**Jean-Louis DuFresne** [Institute Pierre Simon LaPlace—Paris] presented a technique for comparison of CALIPSO observations with cloud predictions from global climate models, along with initial results. Cloud feedback processes are currently believed to be the source of the largest uncertainties in determining the sensitivity of the climate to increasing levels of atmospheric greenhouse gases. Observations from CALIPSO and CloudSat provide an opportunity for more rigorous tests of the representation of clouds in climate models. From this will come an improved understanding of the role of clouds in the climate system.

During a session on cloud modeling, **Jennifer Kay** [National Center for Atmospheric Research—Boulder, CO] discussed recent observations of Arctic clouds by CALIPSO and CloudSat compared to model predictions. Cloud observations from passive sensors are notoriously unreliable in the Arctic and CALIPSO and CloudSat provide a markedly improved observational capability. Anomalously low cloud cover over the Beaufort Sea, observed by CALIPSO and CloudSat, may

**Dave Winker** [Langley-CALIPSO *Principal Investigator*] gave a talk on CALIPSO at the symposium



**Mike Pitts** [NASA Langley Research Center (LaRC)-CALIPSO Science Team member] and **Lelia Vann** [LaRC-Director of Science] converse in front of Pitts' poster at the A-Train Symposium. Pitts is studying CALIPSO observations of polar stratospheric clouds.

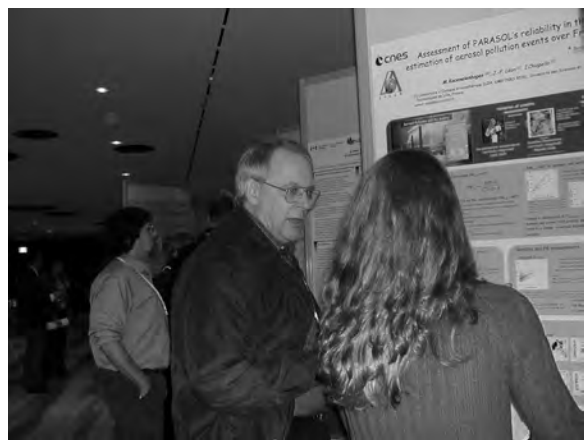
have played a role in the unprecedented retreat of sea ice during the summer of 2007.

The A-train provides aerosol measurements from several different instruments, each with its own unique capabilities. A number of presentations were given summarizing aerosol observations from the Aqua/Moderate Resolution Imaging Spectroradiometer (MODIS), PARASOL, Aura/Ozone Monitoring Instrument (OMI), and CALIPSO/CALIOP instruments. Other presentations focused on benefits from combining A-train aerosol observations with models.

**Anthony Ung** [Institut National de l'Environnement Industriel et des Risques (INERIS)— France] discussed the use of A-train aerosol data by an operational air quality forecast model. MODIS and PARASOL provide the geographic distribution of aerosol while CALIOP measures the vertical profile. Ung discussed applications of these data sets to model validation, as well as the potential for assimilation of the data into the model in the future.

**Mian Chin** [NASA Goddard Space Flight Center—Greenbelt, MD] discussed the use of A-train aerosol observations together with a global transport model to provide estimates of surface aerosol particulate mass that measures 2.5 µm or less (PM2.5), which is a key indicator of air quality. MODIS observations provide constraints on the column aerosol loading, while CALIOP profiles can correct for errors in the vertical distribution of aerosol predicted by the model.

Finally, several talks explored relationships between aerosols, clouds, radiation, and precipitation. Aerosols can affect cloud microphysical and radiative properties and precipitation, but untangling the effects of aerosols from meteorology and dynamics is difficult. Bringing the full capabilities of the A-train to bear on these issues promises advances in understanding these complex processes, which are critical to improving predictions of climate change. ■



**Ray Hoff** [University of Maryland, Baltimore County-CALIPSO Science Team member] meeting with a fellow A-Train Symposium attendee in front of her poster during one of the meeting's poster sessions.

in the news

# 2007 Was Tied as Earth's Second-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 2007 tied with 1998 for Earth's second warmest year in a century—see **Figure 1**.

"It is unlikely that 2008 will be a year with truly exceptional global mean temperature," said **James Hansen**, Director of NASA GISS. "Barring a large volcanic eruption, a record global temperature clearly exceeding that of 2005 can be expected within the next few years, at the time of the next El Niño, because of the background warming trend attributable to continuing increases of greenhouse gases."

The eight warmest years in the GISS record have all occurred since 1998, and the 14 warmest years in the record have all occurred since 1990.

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

The greatest warming in 2007 occurred in the Arctic, and neighboring high latitude regions—see **Figure 2**. Global warming has a larger affect in polar areas, as the loss of snow and ice leads to more open water, which absorbs more sunlight and warmth. Snow and ice reflect sunlight; when they disappear, so too does their ability to deflect warming rays. The large Arctic warm anomaly of 2007 is consistent with observations of record low geographic extent of Arctic sea ice in September 2007.

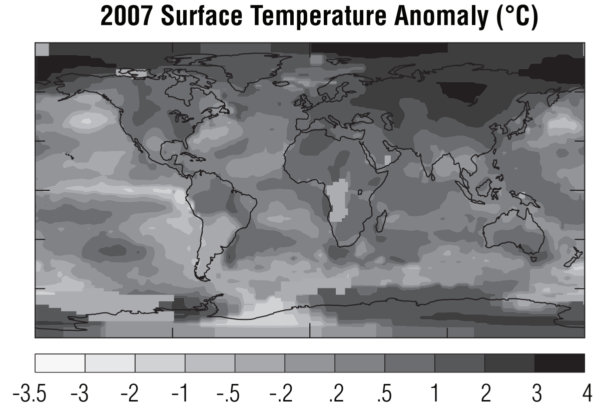



**Figure 2:** The map shows temperature anomalies for the 2007 calendar year relative to the 1951-1980 mean. Warmer areas are dark, cooler areas are light. Largest increases were in the northern hemisphere. **Credit:** GISS

"As we predicted last year, 2007 was warmer than 2006, continuing the strong warming trend of the past 30 years that has been confidently attributed to the effect of increasing human-made greenhouse gases," said Hansen.

A minor data processing error found in the GISS temperature analysis in early 2007 does not affect the present analysis. The data processing flaw was failure to apply NOAA adjustments to United States Historical Climatology Network stations in 2000-2006, as the records for those years were taken from a different database (Global Historical Climatology Network). This flaw affected only 1.6% of the Earth's surface (contiguous 48 states) and only the several years in the 21st Century.

The data processing flaw did not alter the ordering of the warmest years on record and the global ranks were unaffected. In the contiguous 48 states, the statistical tie among 1934, 1998 and 2005 as the warmest year(s) was unchanged. In the current analysis, in the flawed analysis, and in the published GISS analysis, 1934 is the warmest year in the contiguous states (but not globally) by an amount (magnitude of the order of 0.01°C) that is an order of magnitude smaller than the certainty.

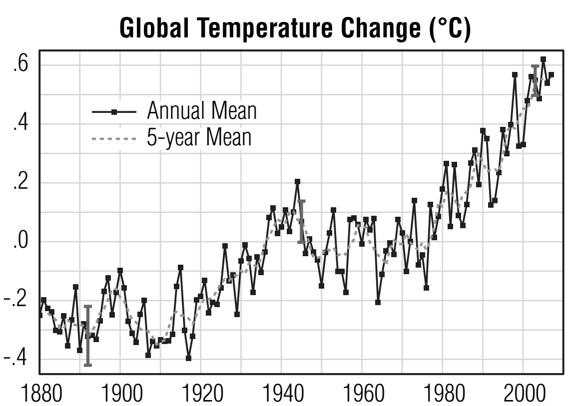



**Figure 1:** Global annual surface temperatures relative to 1951-1980 mean temperature. Air and ocean data from weather stations, ships and satellites. The 2007 point is the 11-month anomaly. **Credit:** GISS

# Ocean-Observing Satellites Help Break Current Records

*Rosemary Sullivant, NASA Jet Propulsion Laboratory, Rosemary.Sullivant@jpl.nasa.gov*

Two different teams of ocean adventurers set records this winter crossing the Tasman Sea. One was the first expedition to kayak from Australia to New Zealand; the other was the first Australians to row across the Tasman Sea. Both took advantage of something that sailors have been relying on since the launch of TOPEX/Poseidon in 1992—maps of ocean currents made possible by ocean altimetry.

The teams consulted with **David Griffin**, a research scientist with Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO). Griffin creates maps of the local waters using sea surface height measurements from the Jason-1, Envisat and Geosat satellites to calculate the location, speed and direction of currents. These maps, which also include sea surface temperature, are available online at *www.cmar.csiro.au/remotesensing/oceancurrents/*.

"The difficult thing about this region is the strong and variable currents," says Griffin, who has worked with many different groups including fishermen, yachtsmen, police, search and rescue personnel, and environmental protection agencies. Griffin is a principal investigator on the Ocean Surface Topography Science Team, an international group of researchers selected to work on the Jason mission. TOPEX/Poseidon and its successor Jason-1 are joint missions of NASA and the French space agency, Centre National d'Estudes Spatiales.

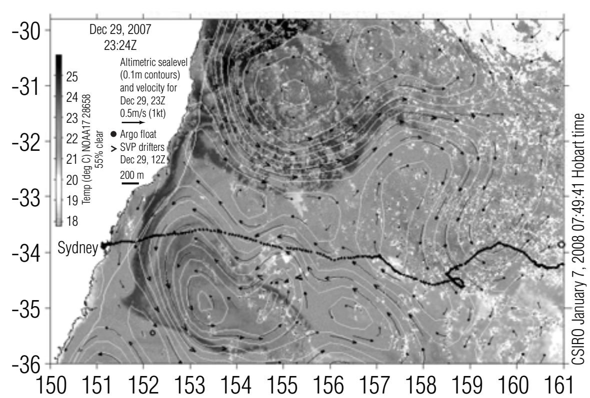
The rowers set off for Australia from New Zealand on November 29, and Griffin received hourly notices of their boat's position. "We had a script going that updated, every hour, what their trajectory would be if they choose various headings to paddle on," says Griffin. "**Andrew Johnson**, the expedition's navigator, had studied the maps on our Web site during preparation for the voyage, so he had a pretty good idea of the array of obstacles and opportunities the ever-changing eddy field of the East Australian Current was likely to present."

"We were certainly lucky with the currents," says Johnson, "but being aware of them was half the battle. At least then you could minimize the negative impact and maximize the positive."

After 32 days at sea, the four Australian rowers successfully completed the 2,200 km (1,400mi) journey on December 30, 2007. The first rowing crossing, done by a single New Zealander in 1970, took 67 days.

The kayakers began their voyage across the "ditch," slang for the Tasman Sea, on November 13, 2007. "They made their tactical decisions by using *Google Earth* to overlay their waypoints on a map of sea surface temperature imagery and altimetric currents that we provide on our web site," says Griffin. They had hoped to make it to New Zealand by Christmas. Instead, they arrived on January 13 after 62 days at sea. "We were biting our fingernails," says Griffin. The launch of the Ocean Surface Topography Mission on the Jason-2 satellite this summer will help ensure that critical ocean altimetry measurements continue into the next decade. ■


Four Australian rowers arrive safely in Sydney, Australia, after crossing the hazardous Tasman Sea guided by ocean altimetry data from NASA's Jason-1 mission. **Credit:** BASEfx Expedition Photo Archives




A sudden change in the currents gave the rowers a boost. The anticyclonic feature *pinched off* from the main flow of the East Australian Current to form an isolated warm core eddy, the northern edge of which propelled the rowers' boat homeward at about 1 m/s, which is equivalent to having one extra rower. To view this image in color please visit: *www.jpl.nasa.gov/images/jason/20080208/3-browse.jpg* **Credit:** CSIRO

# EOS Scientists in the News

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

**Scientist Warns of Warming's Effect on VA**, December 2, 2007; *The Richmond Times-Dispatch*. The sea level could rise 2–5 ft by the end of this century and flood parts of Norfolk, Virginia Beach and other low-lying places in Virginia, says **Bruce Wielicki** (NASA LaRC), adding that the evidence is unequivocal that the planet is warming and human actions are largely responsible.

**World's Sunniest Spots Hint at Energy Bonanza**, December 9, 2007; *Reuters*. NASA has located the world's sunniest spots by studying maps compiled by U.S. and European satellites. **Paul Stackhouse** and **Richard Eckman** (NASA LaRC) state that from satellite data collected over 22 years, the sun blazes down most fiercely on a patch of the Pacific Ocean on the Equator south of Hawaii and east of Kiribati.

**Testing the Climate**, December 24, 2007; *The New Yorker*. A recap of good and bad news related to climate change notes a study that found sea ice is shrinking so fast that summertime ice could be gone within the next few decades, if not years. **Jay Zwally** (NASA GSFC) suggests the Arctic is beyond the point of being simply a beacon for climate change.

**Saharan Dust Clouds Could Aid Hurricane Prediction**, January 7, 2008; *New Scientist*. Dust from the Sahara could provide additional information for improving hurricane forecasts, according to **William Lau** and **Kyu-Myong Kim** (NASA GSFC), who found that Saharan dust over the Atlantic contributed to the drop in 2006 sea surface temperatures, cutting the heat that can fuel hurricanes.

**In Greenland, Ice and Instability**, January 8, 2008; *The New York Times*. **Alberto Behar** (NASA JPL) designed the camera that researchers dropped 330 ft down into a water-filled chamber to study Greenland's plumbing system—just part of the research that scientists are undertaking in order to understand the decline of the ice sheets in Greenland and Antarctica. **Eric Rignot** (NASA JPL) thinks that melt from Greenland alone could result in as much as 3 ft of sea level rise by the end of the century.

**NASA Scientists See Hastened Arctic Warming**, January 9, 2008; *Voice of America*. Arctic sea ice is decreasing faster than models predicted and the Arctic Ocean could be ice-free by summer 2013, according to **Jay Zwally** (NASA GSFC), who adds that Earth's climate could be at a "tipping point," where sea ice will likely continue to decrease even if the climate stops warming.

**NASA: La Nina is Peaking**, January 15, 2008; *United Press International*; Sea surface temperatures in the eastern Pacific are two degrees lower than normal due to La Niña, according to **David Adamec** (NASA GSFC), which has brought wet conditions to the Northwest, cold weather to the Plains, and dry conditions in the Southeast.

**Climate Close to Tipping Point, Says Hansen**, January 11, 2008; *Earth & Sky*. Earth could be close to a climate tipping point, according to **James Hansen** (NASA GISS), at which time only a small nudge from the greenhouse gases could bring about large, fast climate changes.

**High Noctilucent Clouds May Signal Human Impact**, January 14, 2008; *Earth & Sky*. NASA's Aeronomy of Ice in the Mesophere (AIM) satellite has tuned up evidence for human impact on clouds that form near Earth's poles high in the atmosphere, according **Gary Thomas** (NASA GSFC). The clouds—sensitive to small changes in the atmosphere—have increased in number and frequency over the last 120 years.

**Antarctica Ice Loss Faster Than Ten Years Ago**, January 14, 2008; *National Geographic News*, *Reuters*, *The Washington Post*. **Eric Rignot** (NASA JPL) is lead author of a study that used satellites to show that ice loss from glaciers and basins in Antarctica accelerated in the past decade, resulting in billions of tons of ice lost and contributing to sea level rise.

**NASA to Launch Orbiting Carbon Observatory**, January 25, 2008; *National Public Radio*. **David Crisp** (NASA JPL) previews the Orbiting Carbon Observatory scheduled to launch in 2008, and describes how the mission will help researchers map the amount of carbon dioxide in the atmosphere, which could lead to a better understanding of the global carbon cycle.

**More Storms to Batter Southland**, January 26, 2008; *Los Angeles Times*. Storms in Southern California led to avalanches that killed two skiers, and officials warned of mudslides and floods as more bad weather approached. **William Patzert** (NASA JPL) called the situation "serious" but "nowhere near record-breaking."

**El Niño Causing Major U.S. Winter Storms?**, January 28, 2008; *United Press International*. A study by **Siegfried Schubert** (NASA GSFC) and colleagues suggests that some of the intense U.S. storms this winter could be a result of the El Niño events in the Pacific, which were linked to precipitation changes in the United States.

**Workweek Fumes May Make Some Weekends Drier**, February 1, 2008, *Reuters*; February 4, 2008, *The Register* (UK), *Times Online* (UK), *CBC NEWS* (Canada). Rainfall data acquired from a NASA satellite show that midweek storms tend to be stronger, drop more rain and cover larger areas in the U.S. Southeast than weekend storms, according to research by **Tom Bell** (NASA GSFC). The effect could be due to rises in weekday pollution from humans.

**2007 Ice Melt Record in Greenland**, February. 7, 2008; *Earth & Sky*. Satellite data show that 2007 broke the record for melting snow at Greenland's high altitudes, reports **Marco Tedesco** (NASA GSFC), and surface temperatures on the ice sheet that year were 4–6° C above average.

**Lakes Under Glaciers a Key to Sea Level Rise**, February 15, 2008; *Earth & Sky*. Improved GPS data, radar measurements, and images from space show liquid lakes beneath ice sheets in Antarctica, which help the ice sheet flow faster toward the sea, according to **Chris Shuman** (NASA GSFC).

**Book Takes Wide-Angle View of a Changing Planet**, February 17, 2008; *National Public Radio*. **Michael King** (NASA GSFC) and **Claire Parkinson** (NASA GSFC) use satellite images and other data to illustrate major changes on Earth—everything from increasing pollution and shrinking ice caps to deforestation—in a new book, *Our Changing Planet: The View From Space*.

**Arctic Change 'Faster Than People Imagined,'** February 18, 2008; *Earth & Sky*. The extent of Arctic sea ice has decreased over the last 15 years and its thickness has decreased over the last two decades, particularly in 2007, according to **Ben Holt** (NASA JPL). Now, the amount of thin, young sea ice has jumped to 58%, compared to 35% in the 1980s.

***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* ***Stephen.E.Cole@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.*

## KUDOS

**James M. Russell**, Hampton University, was recently named one of Virginia's Outstanding Scientists 2008 by Virginia's Governor, **Timothy M. Kaine**. The press release states "He is a pioneer in satellite atmospheric remote sensing." It cites his most recent research on night shining clouds in Earth's Polar Regions as Principal Investigator of AIM. Our congratulations to Russell on this outstanding achievement.

James M. Russell

**Byron Tapley**, Principal Investigator of NASA's Gravity Recovery and Climate Experiment (GRACE), was honored recently by the University of Texas at Austin and the Cockrell School of Engineering, for 50 years as a "Pioneer of space geodesy….and modern understanding of climate change, oceanography."

Tapley has won numerous awards including election to the National Academy of Engineering, the American Geophysical Union Charles A. Whitten Medal, the American Astronomical Society Dirk Brower Award, an honorary doctorate from Delft University of Technology, and NASA's 2007 William T. Pecora Award to the GRACE Science Team.

The Earth Observer staff wishes to congratulate Tapley on his 50 years of achievements and thank him for the contributions he has made toward the success of the Earth Observing System and, in particular, the GRACE mission.

Byron D. Tapley

# NASA Science Mission Directorate – Science Education Update

*Ming-Ying Wei, NASA Headquarters, mwei@hq.nasa.gov*
*Liz Burck, NASA Headquarters, Liz.B.Burck@nasa.gov*
*Theresa Schwerin, Institute of Global Environment and Society (IGES), theresa_schwerin@strategies.org*

**2008 PENN STATE SCIENCE WORKSHOPS FOR EDUCATORS**
Application Deadline: **May 31, 2008**

Choose from six different content area workshops, designed to meet classroom curriculum requirements:

- Exploring Renewable Energy Technologies and the Materials that Make it Happen (NEW)
- Earth's History: Interaction between life and the environment (NEW)
- Extreme Particle Astrophysics
- Evolution—How important is it to a good science education?
- Telescopes: The Tools of Astronomical Inquiry (NEW)
- Black Holes: Gravity's Fatal Attraction (NEW)

The workshops are an outreach program of NASA's Pennsylvania Space Grant Consortium, the Eberly College of Science, the College of Earth and Mineral Sciences, the Penn State Astrobiology Research Center, NASA Astrobiology Institute, the National Science Foundation-funded Penn State Materials Research Science and Engineering Center, and NASA. For more information and the on-line application, visit *teachscience.psu.edu*.

**MY NASA DATA SUMMER WORKSHOP**
**June 22-27, 2008, Hampton, Va.**
Application Deadline: **April 9, 2008**

NASA Langley Research Center will host a hands-on workshop designed for educators of grades 6-12. The workshop will focus on using NASA Earth System Science data-sets developed for the pre-college education community as part of the MY NASA DATA program. Participating teachers will explore topics in Earth System Science (especially atmospheric science), educational application of data-sets, and hands-on classroom activities. They will attend lectures and tours led by scientists. Participants will also explore how the data-sets can be used to enhance their curriculum and how students can utilize these data for inquiry-based learning and research. A major component of the workshop will be to develop lessons incorporating one or more data-sets. For more information, go to: *mynasadata.larc.nasa.gov/workshop.html*.

New lessons from the 2007 workshop can be downloaded at: *mynasadata.larc.nasa.gov/User_lessons.html*

**NASA EARTH EXPLORERS: SNOW DAY**

Even on the coldest of winter days, the words "snow day" are sure to warm the hearts of school children everywhere. But the number of snow days can vary greatly for kids separated by a relatively short distance. Four students at Roswell Kent Middle School in Akron, Ohio, set out to investigate why. The project has earned them and their teacher a June trip to South Africa. Read more at: *www.nasa.gov/audience/foreducators/k-4/features/F_Meet_the_Next_Earth_Explorers.html*

**SUN-EARTH DAY NEWS**

NASA's Sun-Earth Day team traveled to Barrow, Alaska to join scientists from all over the world during the "Polar Gateways Arctic Circle Sunrise 2008" conference. While there, the Sun-Earth Day team presented a live webcast and produced three on-location podcasts. Subscribe to the podcasts or download the mp3 files at *sunearthday.nasa.gov/2008/multimedia/barrow.php.*

**Eclipse August 1, 2008**

NASA's Sun-Earth Day team is partnering with the San Francisco Exploratorium to produce a live total solar eclipse Webcast and broadcast from China, on August 1, 2008. For details go to *sunearthday.nasa.gov/2008.*

**POLAR-PALOOZA NATIONAL TOUR CONTINUES IN 2008**

POLAR-PALOOZA, the national tour, features high-energy public presentations titled "Stories from a Changing Planet," tales of adventure and science told by a charismatic cast of characters using HD video and authentic props such as a piece of ice core 3,000 or more years old, or caribou and seal skin mukluks (boots), to bring polar research to life; 3-day visits to each site; special programs for schools and underserved youngsters; workshops for K-12 educators and museum volunteers; briefings for local news media and business leaders; and camp-ins for Boys and Girls Clubs. The National Science Foundation and NASA sponsor POLAR-PALOOZA. For cities and sites on the national tour in 2008, go to: *passporttoknowledge.com/polar-palooza/pp04.php.*

**SUMMER INSTITUTE ON CLIMATE INFORMATION FOR PUBLIC HEALTH**
**June 2-14, 2008**

The 2008 Summer Institute on "Climate Information for Public Health" will be held at the Earth Institute, Columbia University, Lamont Campus located in Palisades, New York, and run by the International Research Institute for Climate and Society (IRI), in partnership with the Center for International Earth Science Information Network (CIESIN) and the Mailman School of Public Health.

This two-week training course offers public health decision-makers and their partners the opportunity to learn practical methods for integrating climate knowledge and information into health decision-making processes through expert lectures, special seminars, focused discussions and practical exercises. For more information, go to: *iri.columbia.edu/education/summerinstitute08*.

**S'COOL DATA ANALYSIS (Grades 3-12)**

This Powerpoint presentation from the Students' Cloud Observations On-Line (S'COOL) project provides an introductory tutorial for analyzing cloud observation data from student observations, as compared to NASA satellite observations of clouds from the CERES instrument. For a detailed tutorial download a Powerpoint file at *asd-www.larc.nasa.gov/SCOOL/tutorial/analysis_tutorial.ppt*

## Release of 23-Years of International Satellite Cloud, Climatology Project Data Products

With the recent addition of data for November 2005 to December 2006, the Atmospheric Science Data Center (ASDC) at NASA Langley Research Center announces the availability of 23 years of International Satellite Cloud Climatology Project (ISCCP) data products, covering July of 1983 through June of 2006. Data are available for the following data sets during this period:

- **B3 NATIVE**: 3 hourly data with 30 km resolution
- **DX NATIVE**: 3 hourly data with 30 km resolution
- **TOVS NATIVE**: daily and monthly data on a 2.5° equal area grid
- **D1 NATIVE & HDF**: 3 hourly data on a 2.5° equal area grid
- **D2 NATIVE & HDF**: monthly and monthly 3 hourly data on a 2.5° equal area grid
- **ICESNOW NATIVE**: 5 day interval data on a 112 km equal area grid

Documentation and Tools for working with ISCCP data are available from: *eosweb.larc.nasa.gov/PRODOCS/isccp/table_isccp.html*

ISCCP data are available for ordering from the ASDC Web Ordering Tools: *eosweb.larc.nasa.gov/HBDOCS/langley_web_tool.html*

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Fax: (757) 864-8807
Email: *larc@eos.nasa.gov*
URL: *eosweb.larc.nasa.gov*

# MISR Plume Height Climatology and Visualization Tools Now Available

The NASA Langley Atmospheric Science Data Center (ASDC) and the NASA Jet Propulsion Laboratory (JPL) Multi-angle Imaging SpectroRadiometer (MISR) project announce the release of the" MISR Plume Height Climatology Project" web site: *www-misr2.jpl.nasa.gov/EPA-Plumes/* and the "MISR INteractive eXplorer" (MINX) software tool: *www.openchannelsoftware.com/* (specify MINX in the Quick Application Search box).

The *MISR Plume Height Climatology Project* web site is a publicly-available repository for wildfire plume data acquired using the MISR and MODIS instruments on Terra, and processed to produce an aerosol injection height climatology supporting wildfire, climate change and air quality studies. The data include:

- the location and time of plume observations;
- plume height measurements from which injection heights may be deduced;
- the approximate radiative power of associated fires;
- the direction of transport of plumes;
- the areas of individual smoke plumes; and
- aerosol properties and albedo estimates.

Similar information is also provided for selected regions of dense smoke not clearly associated with specific fire sources (smoke clouds), and whose direction of transport is not easily determined. Currently, the web site contains downloadable data and images for more than 1000 smoke plumes for the Alaska, 2004 and North America, 2002 fire years. Processing of other locations and years is underway and results will be added to the web site as they become available. The data were processed using MINX (see below) and are available at no cost.

MINX is an interactive application written in IDL that functions both as a general-purpose tool to visualize MISR data and as a specialized tool to retrieve detailed plume heights and wind velocities from wildfire smoke, volcanic, and dust plumes. MINX includes high-level options to:

- interactively digitize plumes in order to automatically retrieve heights and winds from MISR multiangle imagery;
- make scrollable, single-camera and multi-camera true-color and false-color images of MISR radiance data;
- create animations of the nine MISR camera images providing a 3-D perspective of MISR scenes;
- display plots of top-of-atmosphere Bidirectional Reflectance Factor (BRF) vs. camera angle for selected pixels;
- apply a geometric registration correction to warp camera images;
- difference images acquired on MISR orbits that share the same ground track;
- create map views of MISR orbit locations; and
- save images and animations to disk in various formats.

## EOS Science Calendar

**April 28-30**
NASA Carbon Cycle and Ecosystems Focus Area Joint Science Workshop, University of Maryland Conference Center, Adelphi, MD. URL: *cce.nasa.gov/meeting_2008*

**May 1-2**
LCLUC Science Team Meeting, University of Maryland Conference Center, Adelphi, MD. URL: *lcluc.umd.edu*

**May 6-8**
9th CERES-II Science Team Meeting, Marriott Hotel City Center at Oyster Point, Newport News, VA. URL: *science.larc.nasa.gov/ceres/meetings.html*

**June 9**
ASTER Science Team Meeting, Tokyo, Japan, Public workshop, June 13. Contact Mike Abrams, *Michael. J. Abrams@jpl.nasa.gov*

## Global Change Calendar

**May 26-30**
AGU Joint Assembly, Fort Lauderdale, FL. URL: *www. agu.org/meetings/ja08/program.html*

**June 1-6**
International Workshop on Solar Variability, Earth's Climate and Space Environment, Bozeman, MT. URL: *solar.physics.montana.edu/SVECSE2008/index.html*

**June 2-6**
Northern Eurasian Earth Science Partnership Initiative (NEESPI) Plenary Science Team Meeting, Helsinki, Finland. URL: *neespi.org*

**June 22-24**
10th Biennial HITRAN Conference, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. URL: *www.cfa.Harvard.edu/HITRAN*

**June 22-28**
2008 GLOBE International Conference, Cape Town, South Africa. URL: *www.globe.gov*

**June 24-27**
101st Annual Air & Water Management Conference, Portland, Oregon URL: *www.awma.org/ACE2008/*

**July 6-11**
IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Hynes Convention Center Boston, Massachusetts URL: *www.igarss08.org/*

**August 3-8**
The Ecological Society of America (ESA), 93rd Annual Meeting, Milwaukee, Wisconsin URL: *www.esa.org/ milwaukee/*

**August 3-8**
IRS 2008; Session on Radiative Transfer and Modeling, Foz do Iguacu, Brazil. URL: *irs2008.org.br/site/index.php*

**August 10-14**
Earth Observing Systems XIII, SPIE International Symposium on Optical Engineering & Applications, San Diego, CA. URL: *spie.org/optics-photonics.xml*

**September 7-12**
10th IGAC International Symposium, Bridging the Scales in Atmospheric Chemistry: Local to Global, Annecy, France. URL: *www.igacfrance2008.fr/*

**September 29-October 3**
59th International Astronautical Congress (IAC), Earth Observation Symposium, Glasgow, Scotland. Call for Abstracts. URL: *www.iac2008.co.uk*

**October 15-18**
Social Challenges of Global Change - IHDP Open Meeting 2008, New Delhi, India. URL: *www.openmeeting2008.org/*

**October 18-21**
Association of Science - Technology Conf. (ASTC) 2008. Philadelphia, PA. URL: *www.astc.org/conference/ index.htm*

**November 17-21**
SPIE Asia-Pacific Remote Sensing 2008, Noumea, New Caledonia. URL: *spie.org/asia-pacific-remote-sensing.xml*

**December 15-19**
2008 Fall AGU, San Francisco, CA. URL: *www.agu. org/meetings/fm08/*

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**The Earth Observer**

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