



## Editor's Corner

*Michael King*

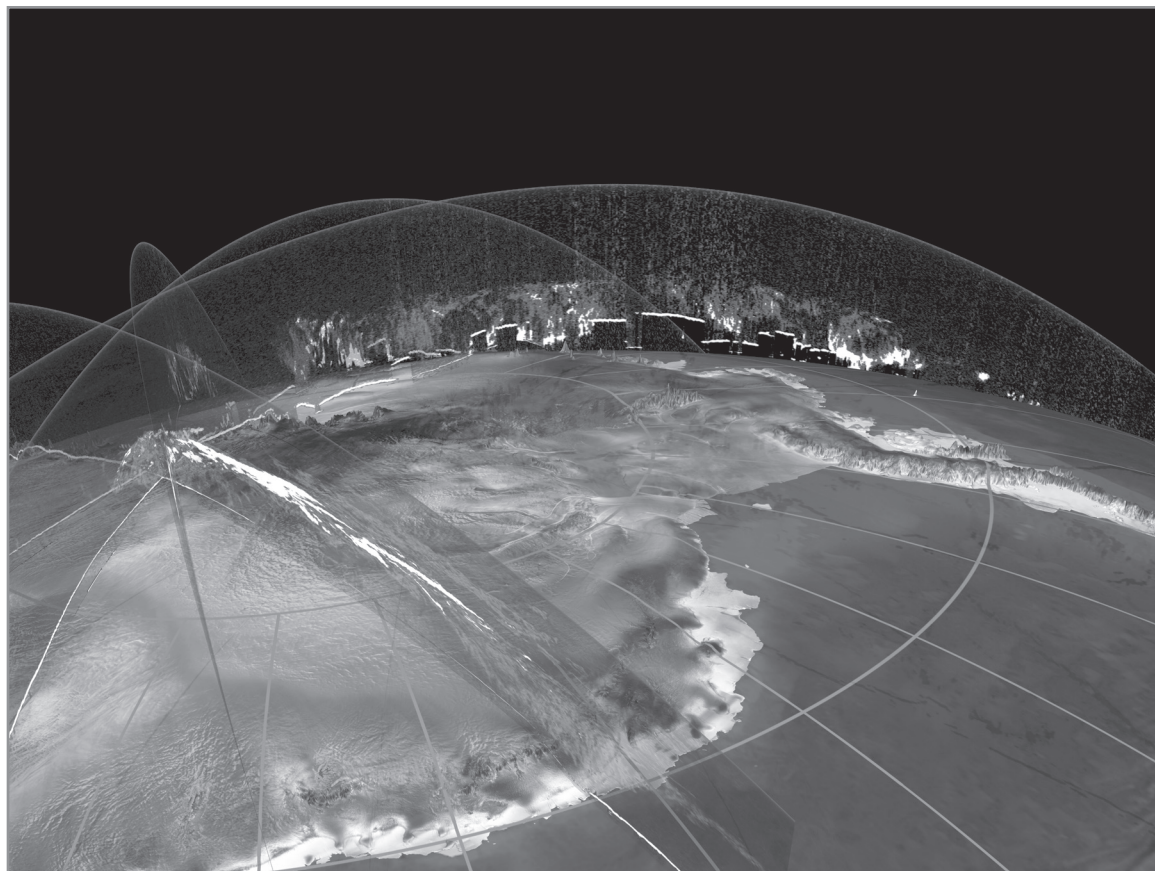
*EOS Project Scientist*

I'm pleased to report that President Bush has signed H.R. 2862, the Science, State, Justice, Commerce, and Related Agencies Appropriations Act of 2006 that provides funding to NASA of \$16.457 billion for the year that started on October 1. This is \$1 million above the President's budget request and \$260.3 million more than NASA received for 2005.

With regard to NASA's Earth Science activities, Congress directed that NASA fund the Glory global climate change research mission at a level \$30 million more than NASA had requested, putting this mission on firmer ground for development for a planned December 2008 launch. Furthermore, it provides an increase of \$15 million to the Earth Science Applications program to support competitively selected projects. The conference report also directed an increase of \$50 million for a Hubble Space Telescope Servicing Mission for a total of \$271 million that NASA plans to fly if the next Shuttle mission, scheduled for next summer, goes well. Also tucked into the appropriations bill are Congressionally directed priorities totaling \$280 million, spread across 185 different projects, that NASA had not requested.

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This image of Antarctica was created using data from the Geoscience Laser Altimeter (GLAS) NASA's Ice Cloud and Land Elevation Satellite (ICESat). Clouds of various thickness are shown, ranging progressively from darker gray (thin clouds) to brighter white (opaque layers). The mosaic of the underlying surface of Antarctica was produced using data from the Canadian Space Agency's RADARSAT mission.



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In other news, the Appropriations Conference Report referenced the Senate language report that says the following concerning the National Academy of Sciences Decadal Survey: "The Committee is encouraged by the efforts of the National Academy of Sciences to devise an Earth Science decadal survey, as has already been done for the other science disciplines funded by NASA. The Committee expects NASA to have an implementation plan, with new start funding attached, to initiate the highest priority missions from the decadal survey in fiscal year 2007. In addition, the Committee fully expects this implementation profile to have a continu-

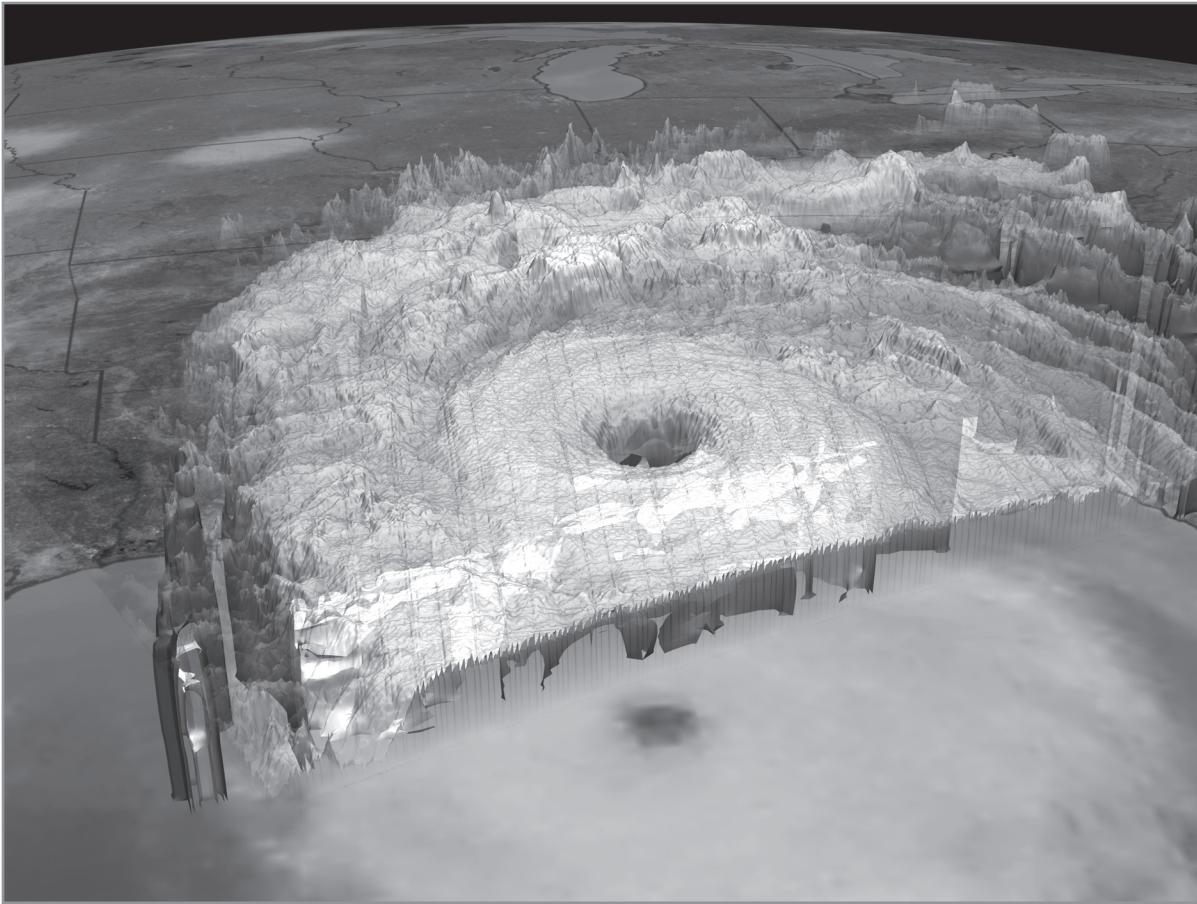
ous mixture of small, medium and observatory class Earth Science missions that guarantee regular and recurring flight opportunities for the Earth Science community."

In reference to the Earth Observing System Data and Information System (EOSDIS), the Senate report says: "The Committee directs NASA to ensure that the EOSDIS and ECS remain the operational foundation of the evolutionary ground system to implement all of the new missions funded as a result of the Earth Science decadal survey."

The Appropriations Conference Report contains language which provides \$4M for infrastructure upgrades at Wallops Flight Facility to accommodate Unmanned Aerial Vehicles (UAVs) at existing hangars, create ground support facilities for medium and high altitude UAVs, define and develop an end-to-end concept of operations including payload-air vehicle integration, and develop a standardized UAV design for civilian agencies. Language in the Conference Report reads: "The conferees note that over the past several years the technology maturity of U.S.-manufactured unmanned aerial vehicles has increased substantially. The conferees believe UAVs could offer NASA a potentially low-cost alternative to traditional Earth Science research missions, thereby opening up new opportunities for research that do not currently exist, and possible improvements in weather- and severe-storm-prediction capabilities. Therefore, the conferees direct the NASA Administrator in consultation with NOAA to report to the Committees on Appropriations on the potential use of UAVs to operate in the near-space environment for a variety of science and operational missions. The report should be completed no later than March 30, 2006."

Following is Conference Report language concerning Landsat: "Funding was proposed in the budget request for NASA, the Department of the Interior's USGS, and NOAA for a Landsat Data Continuity Mission. The Administration proposed a Landsat-type instrument to be flown on a NOAA spacecraft. The conferees now understand that such a mission is no longer feasible for both funding and technical reasons. The conferees direct the above agencies, in consultation with the Office of Science & Technology Policy (OSTP) to report back to the Committees on Appropriations within 120 days of enactment of this Act with an appropriate alternative for a Landsat mission."

I'm pleased to report that on November 24, ICESat concluded its eighth operations period—Campaign 3d—and its third year of active operations. The Geoscience Laser Altimeter System (GLAS) instrument fired its one billionth laser shot earthward on November 18. ICESat measures the Earth's polar-ice



This is an image of Hurricane Katrina on Sunday, August 28, 2005 at 5:30 PM EDT (21:33 UTC) as seen by the Tropical Rainfall Measuring Mission (TRMM) satellite's PR (Precipitation Radar), VIRS (Visible Infrared Scanner), TMI (Tropical Microwave Imager) and the GOES spacecraft. TRMM looks underneath the storm's clouds to reveal the underlying rain structure. The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. Credit: NASA/JAXA.

sheets, clouds, mountains, and forests with three lasers. Crisscrossing the globe at nearly 17,000 mph, ICESat provides unprecedented accuracy in mapping Earth's vertical characteristics, enabling scientists to see objects on Earth in three dimensions.

Meanwhile, as reported previously, NASA Administrator Michael Griffin recently gave the Tropical Rainfall Measuring Mission (TRMM) a new lease on life, extending the mission to at least 2010. NASA is already reaping benefits from that decision as TRMM has been monitoring the extraordinary hurricane activity in the Atlantic this season. This has been a record-breaking hurricane season for the Atlantic basin. For the first time since the National Hurricane Center has been naming storms, they completely exhausted the list of names they had for the Atlantic basin and had to start using the Greek alphabet. To date, twenty-six named storms have formed, the most recent being Hurricane Epsilon. Epsilon is one of only five hurricanes in the past 150 years that have formed outside the official Hurricane Season that runs from June 1 to November 30. Armed with an array of sensors, TRMM can

provide unique images and information on tropical cyclones over the global tropics. To see the most recent data from TRMM, please see [www.nasa.gov/hurricane](http://www.nasa.gov/hurricane).

In addition, sea-surface-temperature data from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) on Aqua has been combined with cloud data from the imager on the NOAA GOES-12 satellite to create a visualization that shows 23 of the named storms that formed during the 2005 Atlantic hurricane season, from Arlene to Beta—save Hurricane Vince which formed too far east to be included. This animation can be accessed from the hurricane resource web site listed above.

Associate Administrator (AA) for the Science Mission Directorate (SMD), Mary Cleave, Deputy AA for the SMD, Colleen Hartman, and Goddard Center Director, Ed Weiler, spoke at an all-hands meeting at Goddard on November 2. This was Cleave and Hartman's first visit to Goddard since assuming their new positions. The meeting also included participants from Wallops Flight Facility in Wallops Island, VA and the Indepen-

dent Verification and Validation Facility in Fairmont, WV. Cleave reiterated the earlier message from NASA Administrator Michael Griffin that NASA is fully committed to maintaining a strong Science Program at NASA, even in the face of reduced budgets. She views having a strong Science Program as an important element in achieving the exploration goals of the agency. Cleave, Hartman, and Weiler all answered questions from the audience concerning future plans for the SMD and the role Goddard will play in those plans.

As of this writing, the launch of the CloudSat and CALIPSO missions that are co-manifested on a Delta 2 launch vehicle have been postponed from November 2005 until mid-February 2006 at the earliest as a result of a Boeing machinists' strike.

Jon Ranson, the Terra Project Scientist for the past 5 years as well as Deputy Project Scientist under Yoram Kaufman for the previous 4 years, has decided to step down and spend more time on his Branch Head duties and scientific research. Ranson has played a key role in the success of the Terra mission over the last 9 years, fighting for and maintaining the science goals set forth by the science community. His successes have been numerous. To highlight a few, he played a major role in the scheduling and implementation of the Terra mission, and in leading the highly successful deep-space maneuvers. Most recently, and extremely important, he was leader of the consolidated extended mission proposal that gives Terra a stable foundation for the next 3 years. We are deeply indebted to Jon for this most

recent accomplishment and his able leadership of Terra over the last 9 years. He will be missed immensely.

Finally, I am happy to report that Marc Imhoff has agreed to serve as Terra Project Scientist, replacing Ranson. Imhoff is an internationally recognized scientist with a background in the use of remote sensing and computer modeling to study human impacts to the biosphere and climate resulting from altered bio-geochemical cycles. Imhoff previously worked as an instrument manager during the formulation of the EOS AM-1 (Terra) mission and later served as the Earth System Science Pathfinder Project Scientist from 2000-2004. Since Terra is one of the nation's flagship missions for Earth science, Imhoff will play a key role in the management of interdisciplinary science and data fusion activities carried out as part of the Terra Extended Mission. I am confident that he will make a very substantial contribution to the Terra mission and represent the Earth science community in an exemplary fashion.

In addition, Si-Chee Tsay, who has a background both in theoretical radiative transfer in the Earth-atmosphere system as well as in radiation instrumentation both from the ground and aircraft, has agreed to continue serving as Terra Deputy Project Scientist as he has under Jon Ranson for the past five years. His background and experience in atmospheric science and in validation and field campaigns, and his substantial effort in helping to formulate the extended mission proposal for Terra, will complement Marc Imhoff's strengths in terrestrial ecology and forestry. ■

# Global Land Ice Measurements from Space

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## GLIMS: Basis, goals, foundation, and organizational structure

Glaciers and ice sheets are the world's chief repositories of fresh water. In many cases, glaciers are almost ideal natural reservoirs, as they store water in frozen form during cold and cloudy (wet) periods and slowly release it during sunny (dry) periods when liquid water is most needed downstream. In common non-ideal cases, glaciers store and suddenly release vast quantities of water, sometimes wreaking havoc downstream if those areas are populated or utilized in critical ways by human beings or the natural world.

It is clear that the world's climate is undergoing rapid, heterogeneous change, and with it, glaciers are also changing. Glaciers are also responsive to climate change over their whole surface areas. Many glaciers are changing in a steady, linear (and, therefore, easily predictable) correlation with climatic perturbations. Some have undergone rapid disintegration. Feedback processes and nonlinear responses can result in unexpected rapid responses of some glaciers and ice sheets. Changes in the amount of the Earth's surface covered by glaciers can have a significant impact on global climate. Therefore, in order to improve our understanding of past, present, and future climate change, scientists require a more-accurate assessment of how the cryosphere, the area covered by ice sheets and glaciers, is changing over time.

In general, it is understood that glaciers are melting at unprecedented rates. However, it is critical to document and understand recent glacier fluctuations to enable predictions of future changes and their impacts on society. The larger ice masses are important because they have a major impact on water resources and hazards and sea-level rise, and because they are an important indicator of past glacial and climatic fluctuations. Glaciers are critical dynamic elements of some multi-national, multi-billion-dollar regional hydrologic catastrophes, and it is urgent for regional and global political stability that scientists understand the state and dynamics and impending future changes of glaciers in these regions (Kargel *et al.* 2005). It is also important to document the extent and distribution of smaller ice bodies. Many of these are not likely to be around several decades from now, making it all the more important that scientists harvest their climatic information now.

Glaciologists, working individually and for large, well-coordinated programs such as the World Glacier Monitoring Service have faced the daunting challenge of inventorying the distribution of the world's glaciers, characterizing their state and dynamics, and quantify-

ing basic glaciological parameters, such as length and area. *The Satellite Image Atlas of the Glaciers of the World* (henceforth, the *Satellite Image Atlas*, Williams *et al.* 2006) has nearly completed the task of producing a pictorial record of the world's glaciers and assessing it for indications of glacier state and dynamics using primarily satellite imaging. In the time since the first civil Earth-resources satellite imaging of the world's glaciers a third of a century ago, satellite glacier imaging has grown in quality, resolution, coverage, and frequency of coverage. Furthermore, the technology available to analyze these images to determine glacier extent and dynamics has also grown dramatically. In the early days, assessments of glacial extent, material units, and ice motion were done manually, but over time, increasingly sophisticated and accurate semiautomatic and automated methods of glacier analysis have evolved to extract information difficult or impossible (and very expensive) to obtain from the ground or by airborne surveys. Technology and semi-automated applications include mapping glaciers and internal material units such as lakes, mapping derivative ice flow fields and changes in glacier extent, and mapping second-derivative changes in flow speeds and acceleration of glacier retreat.

These improvements notwithstanding, a steadily shrinking pool of personnel dedicated to interpreting and understanding glaciological data, especially data pertaining to glacier change, makes the efficiency afforded by technology all the more critical. It also requires organization and coordination, which can enhance efficiency and geographic coverage of glacier changes, provide for checks on accuracy and uniformity of reported data, and reduce excessive redundancy of effort. This is the context in which Global Land Ice Measurements from Space (GLIMS, [www.glims.org](http://www.glims.org)) was developed as a team member project for the Advanced Spaceborne Thermal Emission and reflection Radiometer (ASTER). GLIMS is seen as a logical extension of the *Satellite Image Atlas* and the World Glacier Inventory.

GLIMS makes use of state-of-the-art imaging and image-analysis technology, and draws from a global network of nearly 100 scientists in 25 countries. GLIMS has the goals of: (1) repeat imaging of the world's glaciers by ASTER at up to 15-m resolution, in 14 bands spanning the visible through thermal infrared, and in stereo in one of these bands; and (2) assessing these images for glacier extent and changes. GLIMS relies heavily on imagery from ASTER, and many of its activities fall under the auspices of the ASTER science team, but it also makes use of imaging from the Landsat series and many other satellites, historic map archives, and

field studies. Many members of the GLIMS consortium are further dedicated to practical application of glacier-analysis results to problems involving climate change, current and future water resource availability, and current and future glaciological hazards

GLIMS was designed by Hugh H. Kieffer and began as a small ASTER Science Team project with major ambition, but no funding dedicated strictly to GLIMS. The observational needs for multispectral and thermal glacier observations were considered in the engineering development of ASTER. To make progress toward glaciological analysis on a global scale, it was evident that a global consortium effort was needed. The GLIMS Coordination Center at the U.S. Geological Survey (USGS)/Flagstaff gained small-scale funding through NASA as a Pathfinder project at about the time of ASTER's launch on Terra in 1999. The development of the consortium was a major early activity. Kieffer retired in 2003; recompetition for the ASTER Science Team resulted in J. S. Kargel's assignment as an ASTER Science Team member. GLIMS gained substantial NASA funding starting in 2004 through separate but explicitly linked, competitively reviewed proposals from USGS, the National Snow and Ice Data Center (NSIDC), Portland State University, the University of Maine, and the University of Nebraska at Omaha. Also in 2004, various project-wide coordination tasks, database development, and glacier analysis tasks were funded. In 2005, Kargel resigned from USGS and brought GLIMS leadership to the University of Arizona (Tucson). Foreign institutions are funded at various levels through their own government agencies and other sources. These foreign investigators provide substantial science leverage, since the sum of foreign support substantially exceeds the sum of all American support for GLIMS.

Researchers from all around the world contribute analysis results. To organize and archive these results, a global glacier database has been designed at NSIDC in Boulder, Colorado. Parameters are compatible with and expanded from those of the World Glacier Inventory (WGI).

#### **Types of ASTER image applications.**

ASTER data can be used to monitor short-duration, fast-evolving changes in glaciers. In other cases, ASTER data is combined with data from other sources to create time series to study change. Automated or semi-automated classification of surface units is a key step in extracting the required information from satellite data. One of the major uses for ASTER data in GLIMS is for tracking changes in glacier extent between successive ASTER images or between other data sets and an ASTER overpass. ASTER (and other data) can also be used to track ice motion. The motion of large glaciers

can be detected and mapped using ASTER images acquired only a few weeks apart. Use of good time-series data permits not only just the rate of change to be measured, but also the rate at which change is accelerating or decelerating.

For detailed presentations on selected aspects of GLIMS, we refer the reader to an extended showcase of results in *Kargel et al. (2005)*. Population of the GLIMS database remains the primary goal of GLIMS. Among other future directions, we are striving to understand recent glacier variations and project likely future changes on the basis of climate models and computed assessments of uncertainty in climate models. ■

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## Students' Cloud Observations On-Line: Eight Years of the S'COOL Program

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Since January 1997, in anticipation of the launch of the Tropical Rainfall Measuring Mission (TRMM) satellite, NASA has helped thousands of students and citizen scientists around the world take part in actual scientific experiments through the Students' Cloud Observations On-Line (S'COOL) project. This unconventional collaboration between NASA scientists and students is remarkably beneficial to both groups. The students are able to learn fundamental scientific principles, while the scientists are able to use the students' observations, or *ground-truth measurements*, to assist in the validation of the NASA satellite instruments called CERES.

The Clouds and the Earth's Radiant Energy System (CERES), is a high-priority scientific experiment that includes five space-based instruments on three different satellites. The first CERES instrument was launched on Thanksgiving Day, 1997, on a Japanese rocket as part of the TRMM spacecraft. The second and third CERES instruments were launched on December 18, 1999, on the Terra spacecraft. The final two CERES instruments are on the Aqua spacecraft, which was launched on May 4, 2004. Scientists are using measurements from each of these instruments to study the ways in which clouds affect Earth's climate.

Clouds often occur in many layers that are hard to differentiate from space. Small, thin clouds, and clouds over bright surfaces, such as snow, are also challenging to detect from space. To improve their ability to accurately identify and account for clouds, scientists use ground observations. The number of ground sites available limits these ground observations. To increase the number of ground sites, NASA has engaged students from around the world in the S'COOL project, asking them to take a few minutes from their day to go outside and observe the sky above their school as the satellite flies overhead. The students then report their observations using an on-line form.

"S'COOL has been a great experience not only for the students and teachers but also for the scientists," said **Bruce Wielicki**, co-principal investigator for CERES. "The S'COOL observations also get us into remote places around the world without routine weather stations. So the student data have been part of our plan to test and verify the satellite cloud data."

CERES scientists use the students' ground observations to confirm the accuracy of the satellite measurements from space. They can also compare the surface- and space-based observations to learn more about clouds and climate.

In 2003, a girls' high school in Taiwan partnered with the Central Weather Bureau to conduct a S'COOL workshop. Shown here is Yuyia Wu, one of the teachers at the high school, who taught the students about S'COOL and the scientific concepts associated with the program.





During the S'COOL workshop in Taiwan, students were introduced to the atmospheric science field.

### The Impact of S'COOL on its Participants

As of October 2005, the S'COOL program includes approximately 2,000 registered participants—mostly classroom teachers—from 66 countries around the world. These participants have provided more than 45,000 observations over the past eight years. The wide-reaching arms of the S'COOL program seem to have impacted students in many different ways—from advancing their interest in scientific inquiry [and in clouds], to influencing their choice of college major and thus their future careers, to even uncovering water leaks in their school building.

Encouraging students in their education is an important element of the program. Using hands-on projects like S'COOL allows students to actually use scientific inquiry and see how data are collected and analyzed. It also helps students realize how vast the field of atmospheric science actually is, that they can study atmospheric science in college, and that they can pursue studying the atmosphere as a career. A group of S'COOL students at a girls' high school in Taiwan were so motivated by their participation in the program that several of the school's alumnae reported that they are majoring in atmospheric or oceanographic science in college. The group is an extreme case of the influence that S'COOL can have on students' college and career plans. However, the program does encourage more students to consider scientific career options. In the fall of 2005, another group of S'COOL stu-

dents used what they learned through the program to uncover a hidden water leak under their classroom. A teacher in upstate New York had just begun using the program with her students when they realized that their classroom was very humid as compared to other classrooms in their school, and even to the outdoors. They asked the question: "Why is it so humid in our classroom?" and came up with a hypothesis: "the kids thought it was because we were near the side door and the humidity was coming in somehow." Using their S'COOL hygrometer, a device that measures humidity, they conducted an investigation by keeping track of the humidity levels in the classrooms on their hall, both indoors and out. They analyzed their data and concluded that their humidity readings were definitely higher than readings from outside of their classroom.

The teacher said, "Armed with our data, we brought in the [school] District to investigate, and they had to follow through with the given data! They installed an ink reader that tracked the humidity - and agreed it was too high. Based on their observations which were initiated by our observations, they went into the crawlspace under the classroom and found a leak."

Other students have been inspired in a more artistic way. Students at a school in Italy created a 2006 cloud calendar, where each month features their own photos of a different cloud type. The students are distributing the calendar throughout their school to teach their peers about





During the S'COOL workshop held in Taiwan in 2003, students from a girls' school learned about cloud observations and cloud properties. Here, students are studying the cloud charts in preparation for their observation period.

clouds and the S'COOL program. Through the creativity of S'COOL teachers, the program has been used not only in the science classroom, but also to help students improve their math, observation, writing, technology, and now art skills. The ingenuity of teachers has truly expanded the usefulness of S'COOL beyond its original expected applications.

### **Scientific Results: Matching Satellite Data with Ground Observations**

While S'COOL is aimed at advancing students' scientific knowledge and inquiry, it is also a scientific data validation campaign led by NASA scientists. Currently, nearly half of the student ground observations have correspondences with processed CERES data from the TRMM, Terra, or Aqua satellites. Only student reports within 15 minutes of a satellite overpass time are used for the comparisons because clouds move and change so quickly. Ground observations made outside of the 15-minute window may not accurately reflect the cloud conditions at the time of the satellite observation.

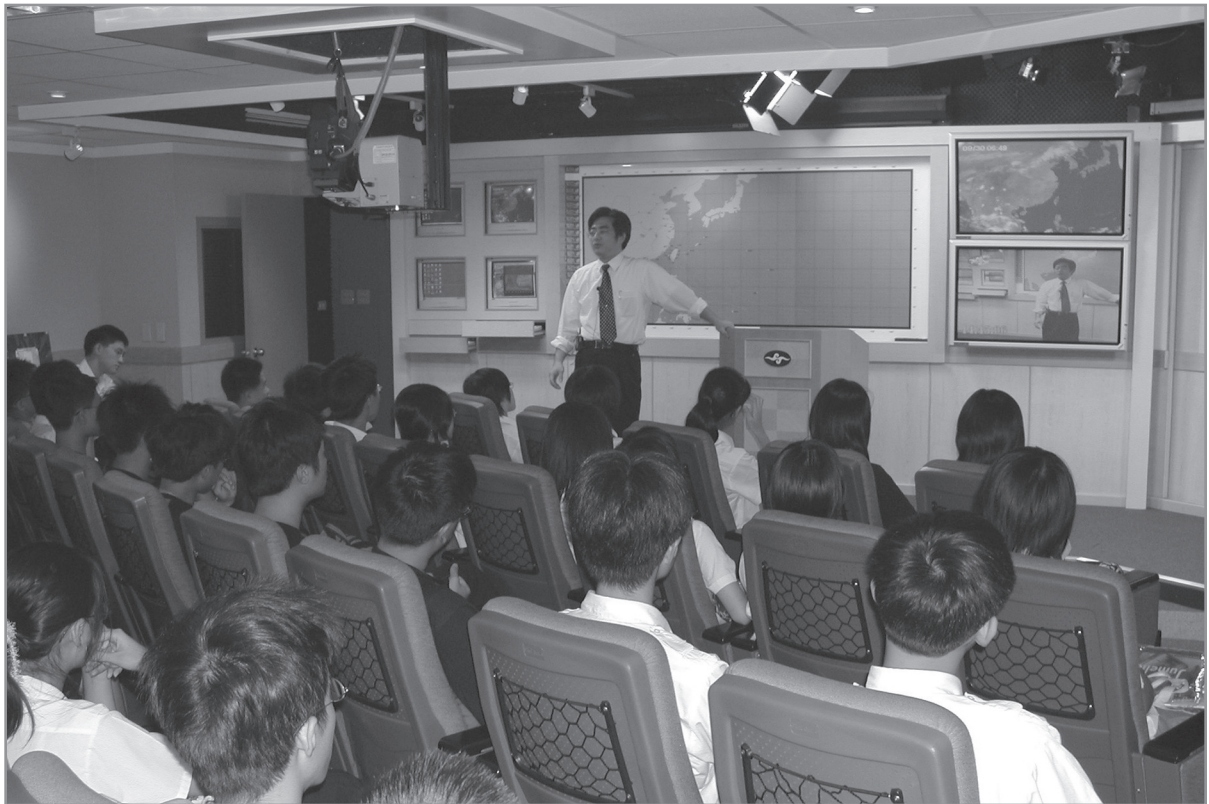
S'COOL data have revealed some key insights for the CERES scientists. For example the CERES instruments, like most satellite passive remote-sensing instruments, have trouble detecting and measuring thin cirrus clouds. While new instruments like the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

will eventually help with this problem, the S'COOL program has shown that ground observation data can also be useful because thin cirrus clouds are perfectly visible from the ground. The student reports allow the CERES team to estimate how often the CERES instrument misses such clouds.

“One of the hardest jobs for CERES is the confident determination of clear sky; that's the easiest part of the observation for the kids,” said Lin Chambers, director of the program. “S'COOL observations can help us to understand the CERES clear-sky algorithms and help the kids understand how clouds connect to climate.”

In addition, S'COOL data are complementary to the satellite data in the case of multilayered or very thick clouds. While the upcoming CloudSat instrument will eventually help quantify multi-layered cloud situations, for now the S'COOL data are able to provide insight on the occurrence of thick, low-level clouds beneath other cloud layers.

Beyond thin and multilayered clouds, the CERES science team has found that there are other issues that can be investigated with the use of ground-truth measurements. Detecting snow cover is a challenge for satellite remote sensing, because the snow surface looks very similar to bright, white, and cold clouds. On the ground however snow and clouds can be easily distinguished.



During the S'COOL workshop in Taiwan, students were introduced to the atmospheric science field and they were able to learn from atmospheric scientists and meteorologists from the Central Weather Bureau.

Thus, the student reports provide a valuable data set for evaluating satellite cloud retrievals in snowy conditions.

Another interesting application of S'COOL data is a research project conducted by **Smadar Shiffman** from NASA Ames Research Center, Moffit Field, Calif. Shiffman's research explored the potential benefits of automated cloud detection and tracking using remote-sensing images. He used the Advanced Very High Resolution Radiometer (AVHRR) instrument on board the NOAA-14 weather satellite of the National Oceanic and Atmospheric Administration as his source of remote-sensing images. He used S'COOL observations as the *gold standard* for labeling training data and for comparing classified test data. For Shiffman, as well as for the CERES scientists, ground-truth measurements are essential for understanding, and thus predicting, the behavior of clouds in our atmosphere.

The CERES team has also started a partnership with the FLASHFlux project to provide satellite data within a week after students report their observations. Before, it took six months or more to provide the data because CERES is a climate effort; not a weather effort. This new capability will allow students to compare their observation with the satellite observations during the same unit of study. In addition, a developing partnership with the MODIS Rapid Response site will allow students to "see" the clouds from above in near real-time.

### The Future of S'COOL

With eight successful years of operation, the S'COOL program has proven itself as a beneficial collaboration for both the students and the scientists. One of the reasons the project has been so successful is its ability to adapt to the needs of the students and teachers. The team recently added geostationary observation times to the project. These stable *overpass* times help teachers to plan, while at the same time providing observations to help validate CERES time interpolation techniques. The CERES team is currently focusing outreach efforts in areas such as Alaska and Canada to help address outstanding uncertainties in polar clouds.

"From our eight-year project, we have found that the best way to get information across—to share the NASA vision—is through two-way communication," said Chambers. "A key component to our program is the interaction we have with teachers—encouraging a dialogue so that we can evolve the program based on all of our needs."

All in all, the team—NASA scientists and K-12 students—is continuing to study the CERES data as well as the S'COOL observations in the quest to improve our understanding of Earth's complex atmosphere as well as its changing climate system. ■

# Combining MISR and MODIS data to automatically catalog smoke plumes in North America

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The Environmental Protection Agency (EPA) is seeking to better understand the effects of wildfires on air quality. This objective is approached through a fusion of data from NASA's Multi-angle Imaging Spectro-Radiometer (MISR) and Moderate resolution Imaging Spectroradiometer (MODIS) instruments, in tandem with innovative data-mining techniques. The MISR and MODIS data are used to automatically identify and classify thousands of smoke plumes over North America. Together the instruments can classify smoke plumes with higher precision and accuracy than with either instrument alone. Additional information on smoke plume heights, when combined with global models, can enable a better assessment of the regional/global impact of forest fires.

MISR has a unique ability to determine the height of smoke plumes using stereoscopic techniques, and the heights are automatically computed at 1.1-km spatial resolution as part of standard MISR processing. Smoke-plume rise is an important component of emissions transport because plume-injection height determines where in the vertical structure of the atmosphere dispersion will begin. In addition, MISR's oblique view angles cause thin smoke to appear more opaque, and the retrieved angular signature helps distinguish smoke from clouds and other aerosols.

MODIS's thermal-infrared sensing capabilities give it the unique ability to detect active fires with high temporal resolution. The MODIS Thermal Anomalies data product uses the 4- $\mu\text{m}$  brightness temperature and the difference between the 4- $\mu\text{m}$  and 11- $\mu\text{m}$  brightness temperatures, in comparison to nearby pixels for context, to detect fires and other thermal anomalies. Support Vector Machines (SVM), a form of supervised classification, are used to detect MISR pixels that are smoky based on color, texture, and angular features. An SVM classifier was trained using dozens of hand-labelled scenes containing smoke, clouds, land, water, and/or ice and snow. Algorithms that involve techniques from the field of machine vision are used to examine those blocks that are found to contain smoke and search for distinctive plume-like shapes. This helps to reject images that contain smoke but no smoke plumes, and often allows the automatic extraction of the plume orientation. Heuristics to order all of the

blocks combine the number of MISR smoky pixels, the number of MISR plume shapes, and the number of MODIS thermal anomalies.

This work is probably the largest research project to date in terms of the volume of MISR and MODIS data jointly analyzed and combined for a science research problem. Although MISR and MODIS are both on the Terra platform, their data are organized in different formats, and data splitting is performed differently for each instrument, so manually combining the products to create a robust global classifier would be time-consuming and difficult. However, the early results from this automated fusion approach are promising.

Statistics on the geographic distribution, extent, orientation, and injection height of plumes are being mined from terabytes of MISR and MODIS data from the summer of 2004, and will be delivered by the end of 2005. In 2006 the same analysis will be applied to several years' worth of data.

The summer of 2004 was selected for initial study because of the record setting fires in Alaska and the adjacent Yukon Territory of Canada. In Alaska more than 6.6 million acres were burnt during the summer of 2004, and records were also set for the number of days of reduced visibility due to wildfire smoke—poor visibility was recorded in Fairbanks on 42 of the 92 days of summer. This shatters the previous record of 19 days in 1977.

Smoke plumes from these fires were intercepted by the DC-8 on the Intercontinental Chemical Transport Experiment (INTEX) field campaign during July and August, 2004, and were evident in the Measurements Of Pollution In The Troposphere (MOPITT) Carbon Monoxide (CO) observations as a continental-scale plume over North America. Knowledge of the injection heights of the emissions from these fires is required for quantitative assessment of their effects on atmospheric composition. We are collaborating with members of the INTEX science team in analyzing the plumes from the Alaskan fires.

Several techniques to mine through the multiple years and terabytes worth of data have been tested. Current

methods operate at the granularity of one MISR block, which is approximately 400 x 140 km. The goal is to find all blocks containing smoke plumes and reject all others. It is preferable to err on the side of more false positives because it is easy to eliminate cases with no plumes, but is impractical to manually examine the entire data set to find missed plumes.

Of the ~22,000 blocks of data from ~460 Terra orbits analyzed so far, there were 635 cases in which smoke was identified in the MISR image and an active fire was present in the MODIS thermal anomalies product. Manually, it was determined that 44 of these contain

distinct smoke plumes. A system is being developed to automatically flag all 44 of these blocks as worth pursuing, while flagging the least number of false positives.

For the smoke-plume heights, preliminary work indicates a mean plume height of approximately 1.7 km for the Alaskan fires in the summer of 2004. Further work will improve this estimate and relate it to fire size. ■

## Announcement

### ESIP Federation Elects 6 New Partners

*November 14, 2005*—The Federation of Earth Science Information Partners (“Federation”) has elected six new partners for full membership. The following projects and organizations represent the latest class of Federation members:

- *The Earth Observing System (EOS) Clearinghouse (ECHO)*, Robin Pfister, NASA Goddard Space Flight Center, Greenbelt, Maryland
- *Environmental Systems Research Institute (ESRI)*, Jack Dangermond, Redlands, California
- *Global Change Master Directory (GCMD)*, Lola Olsen, NASA Goddard Space Flight Center, Greenbelt, Maryland
- *Pacific Disaster Center*, Christopher Chiesa, Kihei, Hawaii
- *Pacific Northwest Regional Collaboratory*, Roger Anderson, Pacific Northwest Laboratory/Battelle, Seattle, Washington
- *A 0.05 Degree Global Climate/Interdisciplinary Long Term Data Set from AVHRR, MODIS and VIIRS Instruments*, Edward Masuoka, NASA Goddard Space Flight Center, Greenbelt, Maryland

“The latest class of membership will propel the Federation toward its goal of providing improved access to the wealth of data, tools, and products available through Federation members,” says **Thomas Yunck**, Federation President. “The steady growth of the Federation is attributed to its position as a leader in the field of Earth observation data, information, and products and the distribution of them into the hands of users. The Federation is developing the Earth Information Exchange, a centralized portal where member data products and tools will be available to researchers, decision makers, educators, and anyone else seeking Earth observation information.”

The Federation now has 89 partners, representing a wide range of Earth science data interests. Federation partners include science data centers, environmental research groups, innovators in the application of environmental data, educators, and technologists. Across these diverse interests, public, private, and non-profit organizations are represented.

The Federation is a consortium of Earth science data centers, researchers, scientists, technologists, educators, and applications developers. The Federation promotes increased accessibility, interoperability, and usability for Earth science data and derivative products. Initiated by NASA in 1997, the Federation provides data, products, and services to decision makers and researchers in public and private settings. The Foundation for Earth Science provides administrative and staff support to the Federation of Earth Science Information Partners. For more information, call 877-870-3747.

## Heavy Rains Can Make More Dust in Earth's Driest Spots

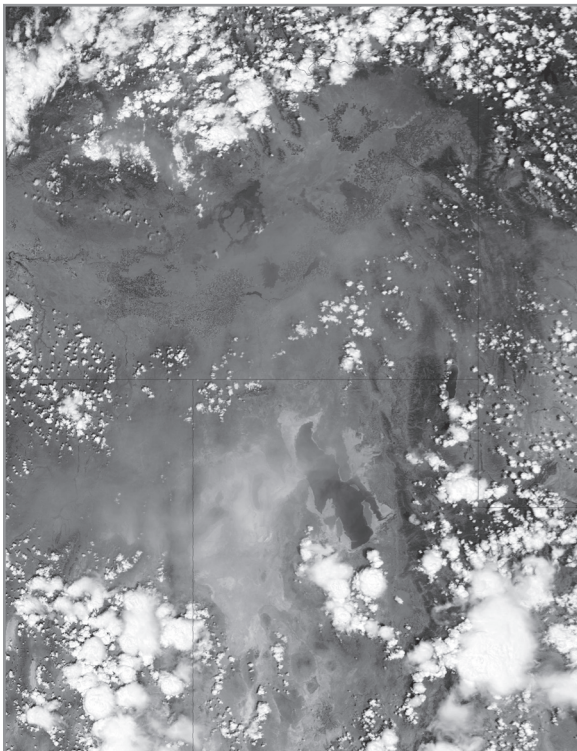
Mike Bettwy, [michael\\_bettwy@ssaihq.com](mailto:michael_bettwy@ssaihq.com), NASA Goddard Space Flight Center

Typically we think of rainfall as cleaning the air by removing dust as it falls through the atmosphere and helping plants grow that protect and hold the soil. But a new NASA-funded study looking at some of the world's dustiest areas shows that heavy downpours can eventually lead to more dust being released into the atmosphere.

Typically drought reduces vegetation growth, increasing soil vulnerability to wind erosion, while rainfall tends to have the opposite effect. In the new study researchers examining 14 of the Earth's dustiest regions found that in some regions, heavy rainfall and flooding leave behind sediments that include fine grain size particles that eventually get carried by winds in successive dry periods, increasing the amount of airborne dust, or emissions, released a year or more later. This is especially common in the Tigris-Euphrates Basin and in the Zone of Chotts in North Africa.

The research also confirms that dust emissions from a specific region can vary considerably from season-to-season, or year-to-year, and are largely dependent on climate patterns.

This image acquired from NASA's Total Ozone Mapping Spectrometer (TOMS) on July 23, 2003, shows a dust storm originating in the western part of Utah (bottom right) and blowing northeastward over Great Salt Lake in northern Utah. Credit: NASA GSFC



In some regions, “[as] in Oman and Saudi Arabia, where heavy rains combine with monsoon-driven winds, precipitation has a more immediate impact and appears to erode the surface crust, or top layer of soil, increasing dust emissions within just a few weeks,” said **Charles Zender** of the Department of Earth System Science, University of California-Irvine, and lead author of the study.

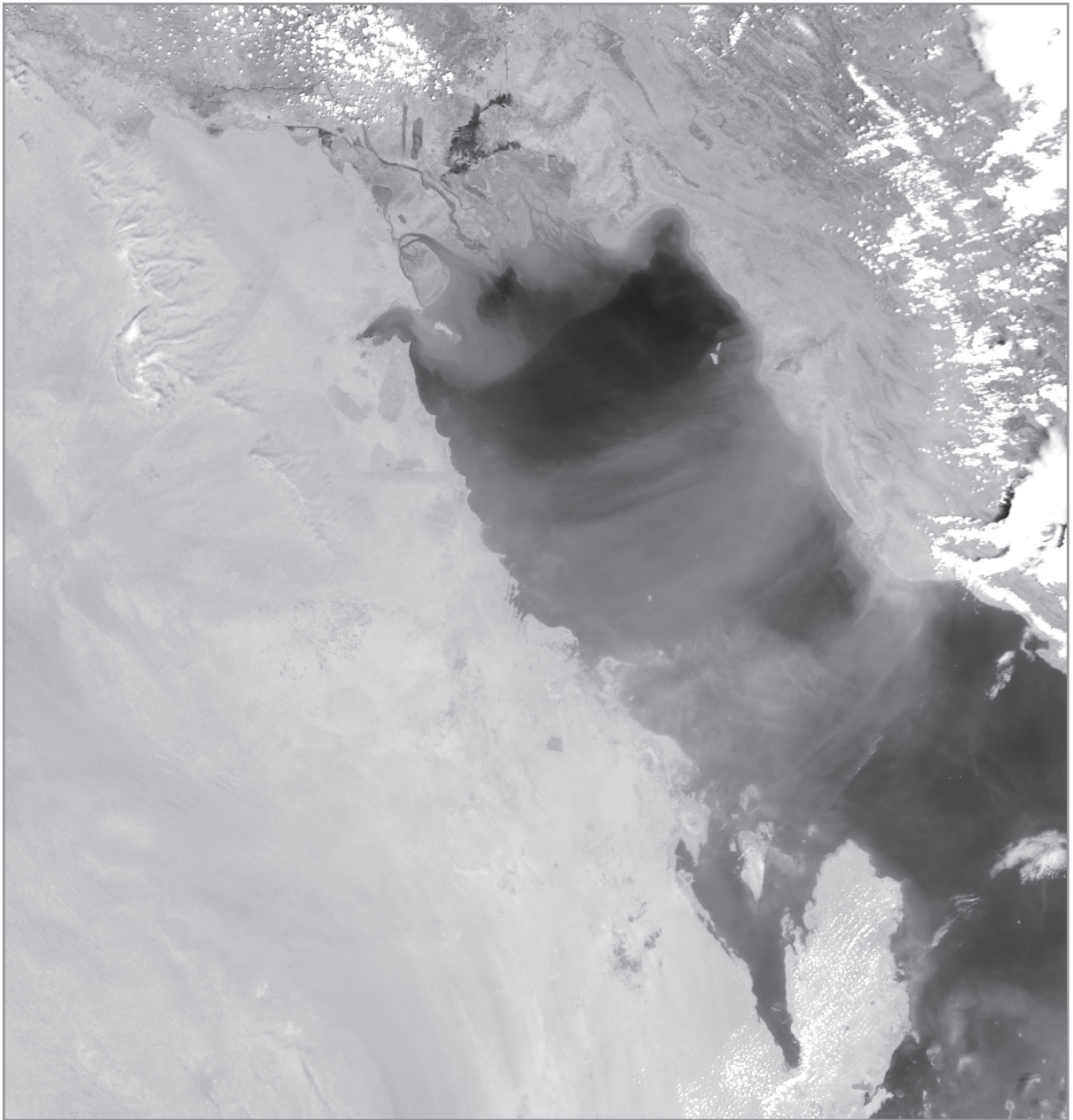
Other areas of the world, including the western United States, the Great Salt Lake in Utah, the eastern Sahel in Africa, and the Lake Eyre basin in Australia, show a more typical response, as precipitation and vegetation lessens the amount of dust released into the atmosphere. In these regions, rain and ground water help form soil layers that diminish the ability of wind to erode and carry soil particles.

Tiny dust particles have a significant influence on climate and weather patterns around the world by reflecting and absorbing sunlight and by serving as a nucleus or surface for water vapor, so that clouds can grow and form precipitation.

The researchers used information for the period 1979-1993 from many sources, including aerosol and dust data from NASA's Total Ozone Mapping Spectrometer (TOMS) satellite, precipitation data from NASA's Global Precipitation Climatology Project (GPCP), and the Normalized Difference Vegetation Index (NDVI) from the Advanced Very High Resolution Radiometer (AVHRR) to analyze surface vegetation cover.

Overall, in the 14 source regions studied, anomalies in dust emissions were closely related to precipitation in 12 of the regions, to vegetation in eight of the regions, and to wind speed in two of the regions. The results suggest that rainfall is the best climate predictor of dust emissions. But other factors, including land features, elevation, the availability of loose sediments, and local distribution of water under the Earth's surface also greatly affect dust emission.

“This study highlights the importance of soil characteristics in dust emission and shows their influence to be more prevalent than previously believed,” said Zender. For instance, some soils may lack free sand-sized particles to initiate dust production, as in the Lake Eyre Basin of Australia. Other areas have soils consisting largely of clay that naturally produce less dust, while some soils may be full of sediments perfect for dust



This image from NASA's Moderate-resolution Imaging Spectroradiometer (MODIS) in April 2003 shows a dust storm (light pixels) over Saudi Arabia, the Persian Gulf, and Iran. Credit: NASA GSFC

production, but are so hard and crusted that none of the particles can escape to produce dust.

While these and other factors are somewhat represented in today's computer models, "they don't adequately account for the formation and destruction of surface soils and how sediment supply for dust production varies from region to region," said Zender. "They also underestimate the monthly-to-yearly variations in dust production and its associated climate impacts."

Future computer models that address these issues will allow scientists to better predict dust production in both the short and long term. Such improvements are

important because dust emissions have a wide impact on climate and weather, from modifying rainfall thousands of miles away, to influencing hurricane intensity and affecting air quality.

The study was published online in July 2005 in the *Journal of Geophysical Research—Atmospheres*. ■

## A Warmer World Might Not Be a Wetter One

Mike Bettwy, michael\_bettwy@ssaihq.com, NASA Goddard Space Flight Center

A NASA study is offering new insight into how the Earth's water cycle might be influenced by global change. In recent years, scientists have warned that the water cycle may be affected by temperature changes, as warmer temperatures can increase the moisture-holding capacity of air.

The global water cycle involves the transfer of water molecules between the Earth's land masses, cryosphere, oceans, and atmosphere. It's a gigantic system powered by the sun, fueling a continuous exchange of moisture between the oceans, atmosphere, and land.

Most climate models have shown that a warmer climate will increase global evaporation and precipitation, but the atmospheric storage of water vapor has not yet been well studied.

Recently, researchers from NASA Goddard Space Flight Center (GSFC), Greenbelt, MD, produced climate simulations of the early and late 20th century. They used sea-surface-temperature (SST) data and two computer models designed at Goddard Space Flight Center to determine how long water stays in the atmosphere. This is one way of measuring how the global water cycle might be influenced by changes in many variables, including temperature and precipitation.

Despite model differences, both simulations showed an increase in global evaporation and precipitation during this period. But, it is important to recognize that simulated atmospheric temperatures also increased during this period, raising the atmosphere's *total precipitable water*—the amount of liquid water in the atmosphere if all water vapor were suddenly condensed.

“By computing a diagnostic for the water-cycle rate, which accounts for total atmospheric water vapor and the average rate of precipitation, the models show the water cycling rate is reduced as the temperature warms,” said **Michael Bosilovich**, lead author of the study, published in the May 2005 issue of the American Meteorological Society's *Journal of Climate*. Co-authors of the study include **Siegfried Schubert** and **Gregory Walker** of NASA GSFC.

When the researchers studied precipitation simulated over land and sea, they found it decreased over land as the local recycling of water vapor was reduced. Oceanic precipitation, however, had an upward trend along with increased sea-surface temperatures, consistent with historical data and earlier studies.

“But, it should be noted that these contrasting land and

ocean trends are not universally applicable to all regions,” said Bosilovich. “For instance, the precipitation over the North American continent increases, while it decreases over the Gulf of Mexico.”

The study also found that land sources of water for precipitation vary considerably within individual regions. Over time, the continental cycle of water appeared to decline, except in the central United States, where it might increase. But, further study is needed with a regional focus to accurately determine local recycling rates.

“In regard to the global scale, satellite data are an essential tool in assessing the rate and intensity of the global water cycle. They help to identify the background state of the climate, but are limited by their short duration of record and deficiencies within historical products,” said Bosilovich. “This study highlights the importance of continued high-quality, well-maintained observations of atmospheric water content and precipitation rates over both the land and ocean well into the future so that we can more accurately assess changes in the water cycle.”

Today, NASA's Aqua and Terra satellites are providing such data by giving new, detailed information on processes that contribute to the water cycle. Ultimately, these findings, coupled with data from future satellites, will be incorporated into regional and global computer models, improving both short-term weather forecasts and long-term climate forecasts. Such seasonal predictions carry significant economic implications and are also critical to water-resource managers in determining water availability and management.

Other research programs like the NASA Energy and Water Cycle Study also use data from NASA satellites to help scientists learn more about the link between climate and the water cycle, improving their ability to predict events like floods and droughts. ■

## It's Always Earth Science Week at NASA Goddard

*Stephen Cole, scole@pop600.gsfc.nasa.gov, NASA Goddard Space Flight Center*

There is something new in the Earth sciences happening every day at NASA's Goddard Space Flight Center, located in the Maryland suburbs near Washington, D.C. At its main location in Greenbelt, Md., and at a scientific institute in New York City and a rocket and airborne flight facility in Virginia, scientists, engineers, and technicians work to keep an eye on the entire planet.

From the ozone hole over the South Pole to the health of forests around the world to air pollution from cities and wildfires, Goddard scientists and engineers see it all. Global views of our planet are received at Goddard every day and distributed to users around the world.

Monitoring the health of the Earth is a big job that requires a lot of different skills. Goddard engineers design and build new tools for seeing Earth from space. Spacecraft-mission operators fly globe-circling spacecraft around the clock. Earth scientists unravel the secrets of how our planet works.

For many of NASA's Earth-watching spacecraft, Goddard is mission control where workers make sure the satellites are in good shape and working properly as they orbit the globe. These satellites include the three big *great observatories*—Terra, Aqua, and Aura—as well as the Tropical Rainfall Measurement Mission (TRMM), which can see inside hurricanes. At the Wallops Flight Facility on Virginia's Atlantic coast, Goddard also runs America's oldest continuous rocket range.

Engineers at Goddard use the latest technology to build new instruments that let scientists see the world in many new ways. For example, a laser instrument developed at Goddard is right now flying over the North and South Poles on the Ice, Cloud, and land Elevation Satellite (ICESat) to make detailed maps of the ice sheets there.

Every single day these satellites and instruments send millions of megabytes of new information down to computers on Earth. To manage all of this information and get it to the people that use it, software engineers at Goddard created the largest scientific data system on the planet: the Earth Observing System Data and Information System (EOSDIS). Scientists, local governments, teachers, and the general public use the online system to get information from more than 30 satellites. One customized system made at Goddard keeps an eye out for forest fires for the U.S. Forest Service.

Goddard experts also help their colleagues in other parts of the U.S. government who watch the weather

every day and keep track of major storms and hurricanes. NASA's TRMM satellite uses radar to look inside a hurricane and measure the rainfall rate. This is an important clue that tells weather forecasters if the storm is going to get stronger or weaker.

But the really big payoff of all this work at Goddard is the new knowledge gained about how our world works. Every year Goddard scientists make important new discoveries. Recent findings include the surprising result that warmer temperatures around the globe may melt more sea ice around the North Pole but create new sea ice around the South Pole. Using a computer simulation, other Goddard scientists found that the *Great Dust Bowl* in the United States in the 1930s was caused by changes in the temperature of the Atlantic and Pacific oceans. Understanding how the world's climate is changing, now and in the future, keeps scientists and computer modelers busy at the Goddard Institute for Space Sciences in New York City.

For more information about how NASA is looking at Earth on the Internet, please visit: [www.nasa.gov/vision/earth/features/index.html](http://www.nasa.gov/vision/earth/features/index.html)

For more information about the American Geological Institute (AGI) Earth Science Week on the Internet, please visit: [www.earthsciweek.org](http://www.earthsciweek.org). ■



## A Heated 3-D Look Into Erin's Eye

*Camille Haley, NASA Goddard Space Flight Center, Science News Team Summer Intern*

Hurricane Erin raced across the North Atlantic and along the eastern seaboard in September 2001. She was used as an experiment for a study to improve hurricane tracking and intensity predictions, allowing meteorologists to provide more accurate and timely warnings to the public. Studies show that temperatures measured at an extremely high altitude collected from a hurricane's center or eye can provide improved understanding of how hurricanes change intensity.

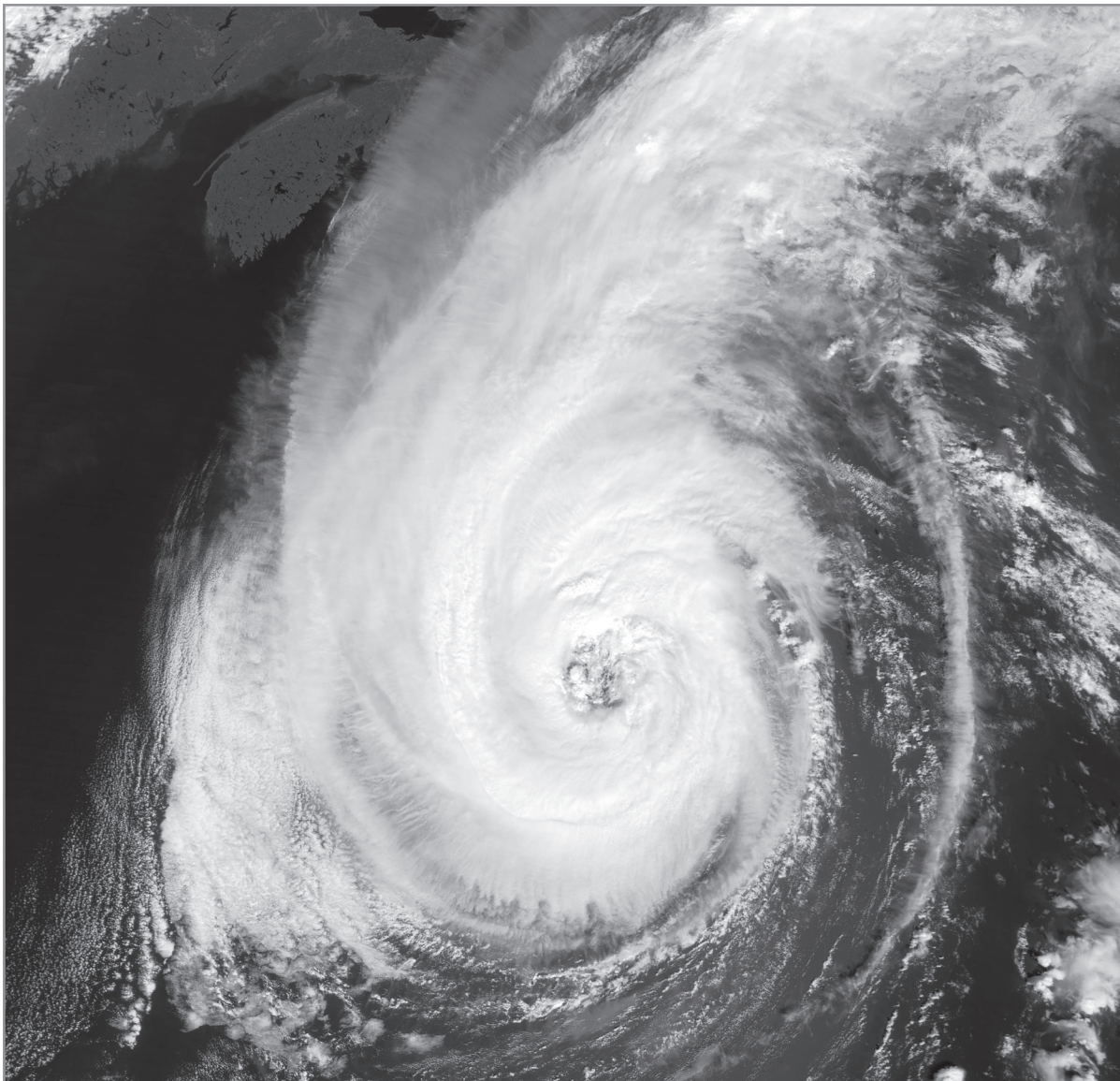
Hurricane Erin was analyzed during the fourth Convection And Moisture Experiment (CAMEX-4), which took place from August 16 through September 24, 2001. The mission originated from the Naval Air Sta-

tion in Jacksonville, FL, and united researchers from 10 universities, five NASA Centers, and the National Oceanic and Atmospheric Administration. CAMEX-4 is one in a series of field research investigations to study tropical cyclones—storms commonly known as hurricanes.

Twenty instrumented packages, called dropsondes, were dropped into Erin's eye by two NASA research aircraft (the ER-2 and DC-8). The special packages included instruments that mapped temperature patterns.

For the first time, researchers were able to reconstruct the structure of the eye in three dimensions from as

On September 11, 2005, Hurricane Erin was making her way northward in the Atlantic Ocean. In this MODIS image, the storm stretches from the latitudes of Virginia in the south, past Massachusetts's Cape Cod, and on up to Maine. The storm churned up the waters of the Western Atlantic and coastal areas along the East coast of the U.S. were impacted with large swells. Credit: NASA/MODIS Rapid Response Team



high as 70,000 feet, down to the ocean surface, in great detail. The dropsondes showed Erin's warm core decreasing while it was rapidly weakening, making the storm more vulnerable to wind shear, a change in horizontal winds, which led to the storm falling apart.

Hurricane Erin's rainfall pattern adjusted quickly to surprisingly small changes in wind speed patterns in the surrounding atmosphere. Weak horizontal winds rearrange rain and wind structure, which create uneven weather conditions around the hurricane's core.

Observations from the study show how warm air in the eye of the storm is linked to reduction in sea surface pressure, which is the basic process that drives the hurricane's destructive winds.

Although little is known about the birth of a hurricane and what causes it to strengthen or weaken, scientists have made substantial steps toward improving predic-

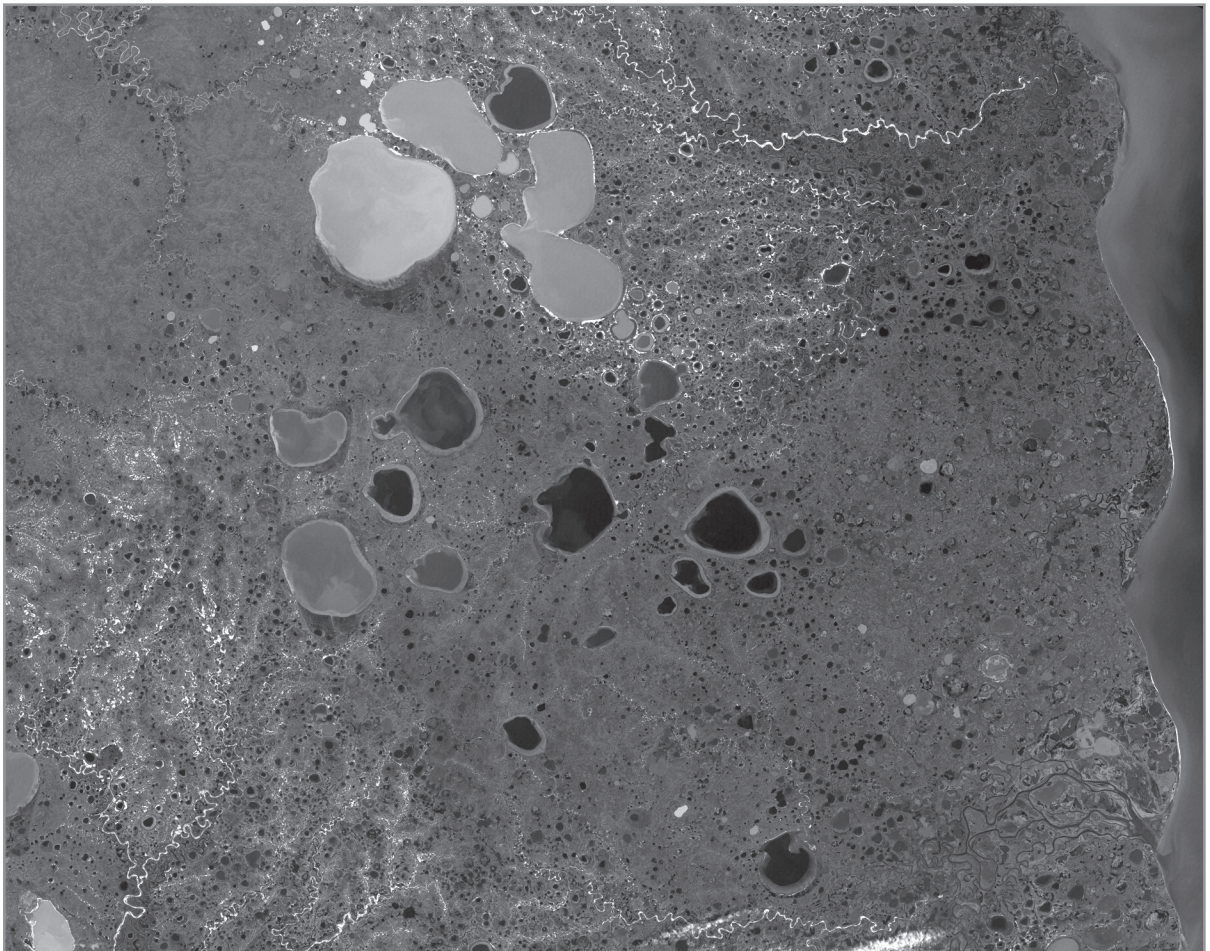
tions of where a hurricane will move or make landfall. The ability to forecast intensity change, however, has always been a challenge for meteorologists.

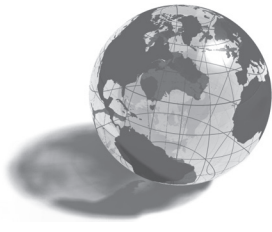
The research done on Hurricane Erin was important because it could help forecasters understand factors that control rain intensity and distribution for hurricanes landing along the Eastern Seaboard.

Flooding is the number one killer from hurricanes in the Western Hemisphere, and the study of a hurricane's rainfall pattern could better prepare us for the next big storm.

This research paper, titled *Warm Core Structure of Hurricane Erin Diagnosed from High Altitude Dropsondes During CAMEX-4* by **Jeff Halverson** and others, is going to be published in an upcoming issue of the American Meteorological Society's *Journal of Atmospheric Science*, CAMEX Special Issue, at the end of 2005. ■

When the Pleistocene Ice Age reached its peak around 22,000 years ago, continent-spanning glaciers covered large sections of North America and Eurasia like a sheet. As the Ice Age waned, the glaciers retreated. Occasionally large chunks of ice broke off from the glacier and became surrounded or even buried by soil and rock debris deposited by the melting ice sheet. Eventually, the blocks of ice also melted, leaving behind a depression in the ground. These depressions are called kettles; when they are filled with water, they are called kettle lakes, or pothole lakes. This Landsat 7 image shows pothole lakes in northern Siberia. NASA image created by Jesse Allen, Earth Observatory, using data obtained courtesy of the University of Maryland's Global Land Cover Facility.





## EOS Scientists in the News

*Rob Gutro, rgutro@pop900.gsfc.nasa.gov, NASA Earth Science News Team*  
*Steven Cole, scole@pop600.gsfc.nasa.gov, NASA Earth Science News Team*  
*Mike Bettwy, mbettwy@pop900.gsfc.nasa.gov, NASA Earth Science News Team*

**Fire Risk High Despite Above-Average Rainfall**, November 29; *Los Angeles Times*. **Bill Patzert** (NASA JPL) interviewed for a story on the ongoing threat of wildfires in southern California despite record setting rains during the previous wet season.

**So Predictable? When It Comes to Making Ski Forecasts, Try Counting Acorns Instead of Clouds**, November 28; *Hampton Roads Daily Press* (VA). November 1; *Los Angeles Times*. **Bill Patzert** (NASA JPL) interviewed for an article highlighting the difficulties associated with ski and winter weather forecasting for an article in the Nature section.

**Public Ocean Literacy**, November 18; *Aquarium of the Pacific's Marine Conservation Institute*. **Bill Patzert** (NASA JPL) assisted in the preparation of "Public Ocean Literacy: What Residents of Southern California Should Know," a 90-page report summarizing results of a CORE-Sponsored workshop.

**NASA's ICESat: One Billion Elevations Served**, November 18; *Science Daily, Innovations Report, Space Daily, Terra Daily*. The Ice, Cloud and land Elevation Satellite (ICESat) fired its one billionth laser shot to obtain elevations from objects on the land, sea and in the air—a number that tops the 6.5 million shots from the Mars Orbiter Laser Altimeter, says **Waleed Abdalati** (NASA GSFC).

**STEREO Spacecraft Arrive at NASA Goddard for Final Testing**, November 9; *Yahoo! News, Innovations Report, SpaceRef.com, RedOrbit.com*. Two Solar Terrestrial Relations Observatory (STEREO) spacecraft arrived at NASA GSFC for major testing in preparation for a mission that will assess the sun and solar wind in 3-D, says **Mark Jarosz** (NASA GSFC) and Michael Kaiser (NASA GSFC).

**Swift Wins "Best of What's New" in Popular Science**, November 9; *Popular Science, Topix.net, Spacewire.net*. Swift, a multifaceted satellite used by researchers including project scientist **Neil Gehrels** (NASA GSFC) to study gamma-ray bursts, won the "Best of What's New" award by Popular Science magazine.

**Sickening Solar Flares**, November 8; *Space Daily, Sciencenews.org, PSIGate*. When the Solar Terrestrial Relations Observatory (STEREO) launches in Spring 2006,

scientist **Francis Cucinotta** (NASA JSC) says researchers will gain a better understanding of solar flares and proton storms that often interfere with radio communications, zap satellites, and worst of all, can penetrate the skin of space suits and make astronauts feel sick.

**AAAS Honors Russell, Lee as Fellows**, November 8; *AAAS*. **Philip B. Russell** (NASA ARC) and **Timothy Lee** (NASA ARC) were named Fellows by the American Association for the Advancement of Science (AAAS) for their work in aerosol properties and atmospheric chemistry.

**Hollywood Portrayal of Hurricanes**, November 6-7; *KCBS-TV Los Angeles*. **Bill Patzert** (NASA JPL) interviewed about the scientific credibility of "Category 7: The End of the World."

**Hurricanes and Climate Change**, November 1; *KNX-AM 1070 Los Angeles*. **Bill Patzert** (NASA JPL) interviewed about the unusually large number of hurricanes this year and climate change in Southern California.

**Lightning Over Africa**, November 2005; *USA Today*. **Steve Goodman** (NASA MSFC) interviewed for a Q&A feature on global lightning patterns (to be published on December 13).

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

## NASA Science Mission Directorate – Earth Science Education Update

Ming-Ying Wei, [mwei@hq.nasa.gov](mailto:mwei@hq.nasa.gov), NASA Headquarters  
Theresa Schwerin, [theresa\\_schwerin@strategies.org](mailto:theresa_schwerin@strategies.org), IGES

On September 23-24, Science Systems and Applications, Inc. joined with the NASA Goddard Space Flight Center Education Office to host the 2005 Coalition for Earth Science Education (CESE) meeting. Seventy-six participants representing academia (teacher preparation and research), large-scale projects, professional societies and organizations, and curriculum materials developers met for two days to discuss issues relating to K-16 Earth and space science education.

The purpose of the meeting was to focus on increasing and improving implementation of Earth System Science (ESS) in K-16 schools by creating a large-scale effort and unified voice to bring about greater and more widespread teaching of ESS. The goals of the meeting were to: (1) establish action items to work toward overcoming barriers to implementation of ESS; and (2) facilitate development of partnerships to work on selected action items.

An e-mail distribution list has been developed for meeting participants to continue discussions and work started at the GSFC meeting and to discuss other topics of interest to the group. A final report is being developed and will be available on the CESE Website ([www.ceseweb.org](http://www.ceseweb.org)). A CD with the final report, speaker presentations, focus group reports, poster abstracts, and discussion highlights from the meeting will also be available. Plans are underway for the University Consortium for Atmospheric Research to host a follow-up meeting in Boulder, CO in November 2006. For further information on the 2005 CESE meeting or to be included in the CESE distribution list, contact **Frank Ireton**, SSAI and CESE Meeting Chair, at [frank\\_ireton@ssaihq.com](mailto:frank_ireton@ssaihq.com).

### HARRIETT G. JENKINS PRE-DOCTORAL FELLOWSHIP PROGRAM (JFPF)

*Application deadline: February 1, 2006*

NASA has partnered with the United Negro College Fund Special Programs Corporation to develop and manage the Harriett G. Jenkins Pre-doctoral Fellowship Program (JFPF), which supports the training of the *next generation of explorers*. The JFPF works to eliminate the shortage of skilled workers in science, technology, engineering, and mathematics (STEM)-related disciplines. Moreover, the JFPF facilitates the development of a more inclusive, multi-cultural and sustainable workforce by providing access and opportunity to those under-represented and under-utilized

persons of society who want to earn advanced degrees. The application deadline is Feb. 1, 2006. Contact the JFPF Administrative Team at [hgjfellows@uncfsp.org](mailto:hgjfellows@uncfsp.org) with questions. Download the program flier at [esse21.usra.edu/JenkinsFLIER04-05.doc](http://esse21.usra.edu/JenkinsFLIER04-05.doc) (MS Word - 302 KB) or [esse21.usra.edu/JenkinsFLIER04-05.pdf](http://esse21.usra.edu/JenkinsFLIER04-05.pdf) (PDF - 236 KB), or visit [www.uncfsp.org/nasaljenkins](http://www.uncfsp.org/nasaljenkins).

### NASA EARTH EXPLORERS MASTERPIECE OF THE SKY

Colorado State University's (CSU) **Graeme Stephens** is uniquely familiar with both the scientific and artistic sides of clouds. While spearheading the development and upcoming launch of CloudSat, a NASA satellite designed to observe clouds at an unprecedented level of detail, the CSU professor of atmospheric science has painted a series of oil-on-canvas pictures featuring a variety of cloud types.

"Art and science have much in common, and much has been written about the common threads between both," said Stephens, who himself wrote such an article for *American Scientist* magazine. "Both, after all, are different expressions of the natural world around us."

Look for NASA Earth Explorers at [www.nasa.gov/home](http://www.nasa.gov/home) (click on the "For Educators" or "For Students" links, then look for the "Meet This Month's NASA Earth Explorer!" graphic or find an article under "Educational Features"). Versions of the article appearing in the For Students K-4 and For Students 5-8 sections are specially written for those grade levels. To access the full collection of Earth Explorers articles, go to [science.hq.nasa.gov/education/earth\\_explorers/](http://science.hq.nasa.gov/education/earth_explorers/). An index of previous articles by topic can be found at [strategies.org/EarthExplorers/EEIndex.htm](http://strategies.org/EarthExplorers/EEIndex.htm).

### SUN-EARTH DAY 2006: Eclipse in a Different Light

The 2006 Sun-Earth Day theme shows how eclipses have inspired people to observe and understand the Sun-Earth-moon system. Join NASA in a journey of exploration, discovery, and understanding as we prepare for Sun-Earth Day and a total solar eclipse on March 29, 2006. Register at [sunearthday.gsfc.nasa.gov](http://sunearthday.gsfc.nasa.gov) to receive a free welcoming packet of materials and monthly updates. ■

## Satellite Missions CALIPSO and CloudSat Partner with GLOBE: Providing a Web Forum for Students and Teachers Worldwide

Becky Boger, GLOBE, [rboger@globe.gov](mailto:rboger@globe.gov)

Barbara Maggi, CALIPSO, [barbara.mmaggi@hamptonu.edu](mailto:barbara.mmaggi@hamptonu.edu)

Debra Krumm, CloudSat, [dkrumm@atmos.colostate.edu](mailto:dkrumm@atmos.colostate.edu)

Recently, students from around the world were treated to an opportunity to interact online with scientists from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and CloudSat satellite missions, both scheduled for launch in early 2006. The event, an online web forum, was hosted at the GLOBE website from October 17-21, 2005. The forum gave students an opportunity to ask questions about the CALIPSO and CloudSat missions and gave them a chance to learn about clouds and aerosols and their possible role in predicting climate change. The asynchronous question and answer web forum not only allowed students from the United States to participate, but students as far away as France, Cameroon, and Thailand participated as well. Mission scientists provided answers in English and French.

Student Quotes from the Burlington County Institute of Technology in Vermont:

- **Jessica Tyrrell**, 12<sup>th</sup> grade: "It was fascinating that there were so many students out there that have the same interests in using satellite data."
- **Laura Quinn**, 12<sup>th</sup> grade: "I think it's great that the GLOBE atmosphere observations will soon include *ground truth* for satellites. For me, that adds more interest to my work."
- **Zoe Bryant**, 12<sup>th</sup> grade: "The addition of tech-

nology in GLOBE will attract younger students, especially girls."

- **Amber Tranchitella**, 12<sup>th</sup> grade: "It's great to be working on projects with other students from around the world!"
- **Dwayne Tattnall**, 10<sup>th</sup> grade: "I am new to the GLOBE Program, but I really see the value of these *chats* in helping me prepare for my future. It gives me a larger view of the world out there."
- **John Moore**, GLOBE Teacher: "The web forum helped students better understand that many complex environmental problems are of a global nature; therefore, the solutions require international cooperation and the sharing of data. After seeing the questions asked in this forum by students around the world, I think the next generation is up to the challenge."

### Related Resources

- **CALIPSO Outreach:** [calipsooutreach.hamptonu.edu](http://calipsooutreach.hamptonu.edu)
- **CloudSat Outreach:** [cloudsat.atmos.colostate.edu/outreach](http://cloudsat.atmos.colostate.edu/outreach)
- **GLOBE:** [www.globe.gov](http://www.globe.gov) ■

**Top:** Participating students from the Indiana School for the Deaf

**Bottom:** Participating students from the Burlington County Institute of Technology, Vermont



## GRACE Science Team Meeting

*Srinivas Bettadpur, srinivas@csr.utexas.edu, University of Texas at Austin*

The Gravity Recovery And Climate Experiment (GRACE), a joint NASA/Deutsches Zentrum für Luft und Raumfahrt (DLR) Earth System Science Pathfinder Program (ESSP) mission for the precise mapping of the Earth's gravity field, held its Science Team Meeting in Austin, TX on October 13 & 14.

The meeting had 75 attendees from the U.S., Germany, France, Korea, and Japan, from disciplines including geodesy, solid Earth sciences, hydrology, water resources, oceanography, and glaciology. The meeting was arranged in four half-day sessions.

On the first day, one half-day session was devoted to a discussion of the project status, and the other to geodetic methods and GRACE data-processing techniques. The second day was devoted to the application of GRACE gravity-field estimates to geophysics. In addition to the oral sessions, posters were put up for viewing on both days.

The meeting website is [www.csr.utexas.edu/grace/GSTM](http://www.csr.utexas.edu/grace/GSTM), which also leads to pages with session description and meeting programs. An electronic (pdf) copy of the meeting proceedings will become available.

**Byron Tapley**, the GRACE Principal Investigator (PI) opened with welcoming remarks. Tapley addressed the results from the 2005 NASA Senior Review. At this review, GRACE Science had been rated as *compelling*, and a mission extension to 2009 had been approved. Tapley described the findings of the Senior Review Committee, including the potential for future calibration campaigns, expanding the multi-mission applications of GRACE data products, wider dissemination of GRACE data and results in the user community, and the future product improvements. Following the PI, the operations manager presented the project status. The satellite resources, including fuel, battery life, altitude decay, and thruster actuations portend a total mission lifetime of at least 9 years from launch. Plans for the swap in position of the twin GRACE satellites, to be executed in December 2005, were also presented.

The Science Data System (SDS) presentations followed in the rest of the morning session. Level-1 processing, which converts raw data into Level-1 metric distance, distance change, acceleration, and orientation data products, reported nominal operation. Practically 100% of mission data are recovered on a routine, automated basis. The on-board alignments and calibrations were reported as stable and nominal. There are at present no plans to upgrade the Level-1 data products. Routine delivery of Release-01 Level-1 products is expected to continue.

Level-2 centers at the University of Texas, Center for Space Research (UTCSR), GeoForschungsZentrum Potsdam (GFZ), and NASA's Jet Propulsion Laboratory (JPL) reported progress in the development of the next generation gravity field (Level-2) data products. Primary improvements are in the area of upgrades to the background gravity models, relative to which monthly corrections to the Earth gravity field are extracted from GRACE data. Prior to the meeting, the Science Data System (SDS) centers had produced a one-year sample Level-2 data set that had been evaluated for improved science content. The results were reported in this session. The next-generation products show significant improvements over the first-generation products—this improvement was noted to be “evolutionary, but not revolutionary.” Some notable features of the improvement include fixing the unstable estimates of the Earth oblateness parameter ( $J_2$ ) from the previous estimates, and improvement in accuracy at the lower and mid wavelengths. A longer, two-year span of these improved monthly solutions from all three centers was made available to the GRACE Science Team, for assessments and further discussions during the Fall 2005 AGU meeting.

On Thursday afternoon, the talks on geodesy and processing methods roughly divided into three parts. In the first part, four groups outside the GRACE SDS presented their results on the extraction of gravity signals from GRACE measurements, comparing different techniques to the GRACE SDS. Two papers focused on local/regional methods to extract regional gravity variations directly from GRACE inter-satellite tracking data. They showed variability estimates over the Amazon River basin and Antarctica, at shorter temporal resolutions than monthly intervals currently reported by the GRACE SDS. Three other papers reported results from alternate global dynamical methods of extracting monthly spherical harmonic gravity models, discussing their differences relative to the operational Level-2 processing by the GRACE SDS.

The second part of Thursday afternoon focused on methods for mitigation of residual errors in monthly geopotential models. The presentations focused on ameliorating specific, north-south-aligned striped patterns of errors evident in GRACE gravity estimates. These were done either through empirical corrections to the spherical harmonics of monthly fields, or through a suitable design of spatial smoothing filters that take into account the spectral distribution of errors in the monthly gravity fields. Improved extraction of signals to as low as 400-km resolution of equivalent water layer variations was reported using these *a posteriori* correction methods.

For the remainder of Thursday afternoon, and also in the posters, presentations touched on the role of GRACE gravity-field products in the definition and error estimation of the next-generation geoid models in the United States, Canada, and in Europe. Other posters addressed precise-orbit determination of GRACE satellites, determination of daily, long-period variations, error calibration of simulation models, and ground validation.

On Friday, the meeting covered the application of GRACE gravity variability estimates to glaciology, hydrology, and the ocean sciences, respectively in three sessions. Common threads to emerge across most of the presentations were that: (1) having uniform quality estimates over long duration was of the utmost importance; and (2) smoothing methods were key to extraction of geophysical signals from the GRACE data products.

Presentations and posters on global geodynamics showed success in the ability to extract surface-mass loads and geocenter motions from a combination of GRACE and other geodetic data. The results also showed good agreement between the new-generation estimates of degree-2 harmonics (moment/product of inertia) from GRACE and estimates from other space geodetic techniques and models.

Estimates of long-term mass change over Greenland from GRACE were shown to agree with other such estimates; patterns of change over Southeastern Alaska and over Hudson Bay regions from GRACE were also shown to be in agreement with glacial isostatic adjustment (GIA)-model-derived rates. The Patagonia region was seen to be unfortunately aligned relative to the N-S striped errors in GRACE estimates, and an 8-year time series with current error levels was thought to be necessary to resolve patterns of secular change to degree/order 20 or so.

Presentations on hydrological applications of GRACE continued addressing river-basin-scale variability. One presentation evaluated the annual variability predicted by five of the Intergovernmental Panel on Climate Change (IPCC)-candidate hydrological models, and showed their agreement with GRACE on a global scale. Important regional differences in amplitude and phase between the two were shown in the low latitudes. Another talk discussed the prospects of application of GRACE hydrology estimates to decision-support systems, with applications to water-resources planning, weather/climate prediction, and stream-flow forecast. The key requirements for such applications were identified as short, 5-10 day integration span, very short latency, and a horizontal resolution of a few km—which at the moment are not available from GRACE. Nevertheless, GRACE was shown to be

capable of contributing through spatial, vertical, and temporal disaggregation of contributions to the ground-water storage changes.

Oceanographic presentations covered the applications of both the static and time-variable gravity-field components of the GRACE gravity fields. Some common points to emerge from the presentations and posters were: (1) the role of ocean model assumptions related to mass/volume conservation and exchange across the land-ocean boundary are becoming more important if GRACE results are to be reconciled with oceanographic models; and (2) the product accuracy requires further improvement. The mean field was used in one presentation to estimate north-Atlantic dynamic topography to 300-km resolution in conjunction with satellite altimetry. Another presentation discussed the use of time-variable estimates over the ocean and emphasized the need for uniform-quality monthly gravity solutions. One paper showed that oceanic geoid variability estimates that were heretofore thought to be too large, could perhaps be explained by a self-consistent treatment of contribution of hydrological fluxes to the definition of the geoid over the oceans. GRACE-derived ocean-bottom pressure was shown to contain the characteristic, non-seasonal variations of the subarctic ocean bottom pressure gradient predicted by oceanographic models. This oscillation is of interest as it has been shown to lead the El Niño by approximately one year. Other regions addressed with GRACE data included the central Pacific and the Antarctic Circumpolar Current. The final presentations within the oceanography section showed that sensible corrections to the *a priori* ocean-tide models could be obtained from using the GRACE data in an *in situ* regional analysis. ■

## International Polar Year Workshop Held at Goddard

David Herring, [david.d.herring@nasa.gov](mailto:david.d.herring@nasa.gov), NASA Headquarters

Paula Coble, [paula.coble-1@nasa.gov](mailto:paula.coble-1@nasa.gov), NASA Headquarters

On September 8-9, 2005, NASA held a kick-off workshop at Goddard Space Flight Center to begin planning the agency's education and public outreach strategy in support of the Fourth International Polar Year (IPY). To be conducted from March 2007 through March 2009, the IPY is an internationally coordinated suite of scientific field campaigns to study climatic and environmental change in the polar regions as well as the teleconnections linking the polar regions to the rest of the globe.

NASA is looking forward to joining with its international partners as a major contributor to IPY, just as it played a major role in the International Geophysical Year of 1957-58, shortly after the agency was born. Given NASA's fleet of sophisticated Earth- and Sun-observing satellite sensors currently in orbit, its air- and surface-based data collection facilities, and its large, diverse community of Earth system scientists, our agency has considerable assets to contribute. Likewise, NASA plans to contribute significantly to the other international years of science currently being planned—such as the International Heliophysical Year (IHY), and the Electronic Geophysical Year (eGY). (For more information about the research foci of these international years of science, please visit their Web sites, at [www.ipy.org](http://www.ipy.org), [www.ihy2007.org](http://www.ihy2007.org), and [www.egy.org](http://www.egy.org), respectively.)

The purpose of the September 2005 IPY Workshop at Goddard was to update the Education & Public Outreach (EPO) community across the agency on the state of the science in polar research, and to begin the process of cross-mission and cross-center communications in planning NASA's EPO strategy for IPY. The specific objective of the workshop was to discuss the following:

- Who are the key EPO personnel within NASA that will contribute to IPY?
- What are NASA's main themes and messages, and how do they mesh with those of our international partners?
- What NASA-unique contributions will we make to IPY?
- Who are our target audiences and how will we adapt our strategies to serving their needs?
- Can we devise an overarching framework, or *scaffolding*, to which all NASA IPY EPO participants can contribute?

To review the agenda for this workshop and access any of the presentations, please visit [esdepo.gsfc.nasa.gov/calendar/view.php?id=64&year=2005&month=09&day=08](http://esdepo.gsfc.nasa.gov/calendar/view.php?id=64&year=2005&month=09&day=08).

### IPY Science Presentations

On the first day of the workshop, participants received a series of scientific presentations in eight different topic areas. **Robert Bindshadler** (GSFC) began with a presentation about ongoing changes to ice sheets and sea ice in the polar regions, and the various NASA satellites being used today to study how and why polar ice is changing. Earth's poles are among the most rapidly changing regions on Earth due to global climate changes. He said the *positive feedback loop* at work in the polar region is of particular concern to glaciologists today—as the ice sheets retreat, the surface changes from a bright white reflector of sunlight, to a relatively dark absorber. This absorption will likely help to warm the region, which will speed the melting and iceberg-calving process, which will expose more ground surface, which will lead to more absorption, and so forth. Moreover, he said, there is nothing in our current understanding of the physics of ice-sheet dynamics that says there cannot be a large-scale collapse of the ice sheets on Greenland or West Antarctica. Such a collapse, he noted, would significantly raise global sea level. Thus, the polar-ice situation warrants further scientific study and monitoring and will be a central focus of IPY. (The article on GLIMS in this issue discusses monitoring glaciers and ice sheets.)

**Richard Lammers** (University of New Hampshire) gave a presentation on water dynamics in the Arctic climate system. Lammers showed maps of the major river-drainage basins that empty into the Arctic Ocean, but pointed out that we currently have only very sparse data about freshwater discharge rates. Lammers said the major features of the Arctic water balance, and how they vary over time and space, are not well understood. Therefore, it is hard to predict how the Arctic water cycle will change as climate changes. Lammers noted the ArcticRIMS Data System site as a potentially useful scientific resource ([RIMS.unh.edu](http://RIMS.unh.edu)). Part of the IPY focus will be to better understand polar-water-cycle dynamics and how they may be impacted by climatic change.

**Jerry Brown** (International Permafrost Association) presented on permafrost and coastal dynamics. As the polar regions warm, we are likely to see increased and accelerated thawing of *permafrost*—frozen soil beneath the surface. Such thawing is a natural hazard, as it can cause surface collapses that destroy homes, buildings, and other human infrastructure, such as oil pipelines, railways, etc. Thawing permafrost is also significant climatologically. Once thawed, the carbon locked in the soil is available to bacterial decomposition, thus releasing carbon dioxide into the atmosphere and potentially adding to global warming and setting up a *positive feedback loop*. He invited folks to attend the 9th



International Conference on Permafrost in Fairbanks, AK (see [www.nicop.org](http://www.nicop.org)).

**Paul Newman** (GSFC) gave a brief historical overview of studies about stratospheric ozone loss, including NASA's role. He said ozone loss is one of the greatest examples of human impact on Earth's atmosphere. Newman showed time series data from the TOMS and OMI (aboard Aura) sensors that demonstrated the evolution of the Antarctic ozone depletion over time. The *ozone hole* is back again this year, and is quite large in extent. Newman noted that while the stratospheric ozone layer is projected to recover over this century, it has not recovered yet and currently shows no signs of doing so. Because ozone blocks harmful incoming ultraviolet radiation from the Sun, it is essential for life on Earth's surface. Thus, monitoring ozone will be a vital part of IPY. Newman encouraged folks to visit his new Ozone Watch Web page ([ozonewatch.gsfc.nasa.gov](http://ozonewatch.gsfc.nasa.gov)).

**Brent Christner**, (University of Montana), a microbial ecologist, gave a presentation about life in the cold and dark of Antarctica's subglacial lakes. He said he is not aware of any research that NASA has ever directed toward life in subglacial lakes, although such work certainly has relevance to scientists' search for life on other planets. Scientists once thought that Antarctica was a lifeless *desert*, but their new view is that subglacial lakes can be an *oasis of life*. Most of our knowledge of such lakes comes from bore hole data over Lake Vostok, which has been isolated from the atmosphere and sunlight by a very thick sheet of ice for 15 million years. While it is cold and dark, there are temperature differences and scientists have detected a circulation pattern in the lake. The lake's shallows appear to be more biologically productive than its deeper waters, and the lake is supercharged with gases. How does life persist in such conditions? Christner speculated the food web there could be *chemoautotrophic*, but the answer is currently unknown. He reported on the recent formation of the Subglacial Antarctic Lake Environments (SALE) Working Group in which scientists are studying the formation and evolution of such environs. (For more details, see [salepo.tamu.edu/us\\_sale](http://salepo.tamu.edu/us_sale).) He said NASA's development of unmanned underwater vehicles could prove invaluable to such studies—on Earth and on other worlds.

**Seiji Kato** (LaRC) gave a presentation about Earth's radiant *energy budget* and the ways in which it is influenced by the polar regions. Kato said tracking Earth's energy budget is like *bookkeeping*—we monitor how much energy comes from the Sun as compared to how much energy is reflected and emitted by Earth back to space. The Sun beams the energy equivalent of 10 power plants per person currently inhabiting the planet. But as the surface changes—particularly snow and ice extent in the polar regions as well as at lower latitudes—so does the amount of sunlight reflected back to space. Kato noted that even small percentage changes of sunlight absorbed at the surface can make a big difference in Earth's climate. Key questions are: how

much will the polar regions change over time, and how will changes in sea-ice extent drive changes in the atmosphere, including cloud formation? And overall, how will those changes affect the energy budget? These questions will be explored as part of IPY.

**Tony Freeman** (JPL) gave a presentation about exploration systems and technologies. "What are the needs of an explorer?" he asked. "They are air, power, water, fuel, mobility, protection against natural hazards, communications, and self-cleaning space suits." Freeman presented the current exploration roadmap and timeline for exploration of Mars in the next decade. Whereas almost all landings on Mars have been in the equatorial region, any human landings will almost certainly target the polar regions because there is water there in frozen form. He elaborated on some near-term research foci about Mars, including studies of the history of water on Mars, sub-surface water, and water-formed minerals. Mars-Earth analogs will be an important thread of study during IPY.

#### EPO Discussions

On the second day of the workshop, participants divided into four discussion groups as a function of target audience, including:

- formal education
- informal education
- public media
- outreach/inreach

Although overarching themes are still being discussed at this time, NASA's expressed interests include:

1. understanding contributions of polar glaciers and ice sheets to sea level;
2. understanding polar feedbacks and the role of polar regions in the Earth system in terms of chemistry and climate;
3. understanding high-latitude biogeochemical and ecological processes and their relationships within the Earth system;
4. using the polar regions as analogs for exploration of other planets and test-beds for planetary operations; and
5. comparing the poles to polar regions on other planets.

Chaired by **Ming Ying Wei**, (NASA/Headquarters) an IPY planning group has been formed at NASA HQ to coordinate and guide efforts across the agency in planning and conducting the specifics of NASA's EPO strategy for IPY and IHY. There will likely be an IPY/IHY funding opportunity announced in calendar year 2006 to help support activities. **Geoffrey Haines-Stiles**, of Passport to Knowledge, has received a grant to assist with development of a plan for the agency. He is currently planning a follow-up workshop at JPL (November 30) and at Ames Research Center (December 2). ■

## SORCE Science Meeting Addresses “Paleo Connections Between the Sun, Climate, and Culture”

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

Gary Rottman, [gary.rottman@lasp.colorado.edu](mailto:gary.rottman@lasp.colorado.edu), Laboratory for Atmospheric and Space Physics, University of Colorado

Paul Mayewski, [paul.mayewski@maine.edu](mailto:paul.mayewski@maine.edu), Climate Change Institute, University of Maine

The third annual SORCE Science Meeting was held in Durango, CO on September 14-16, 2005, and concentrated on the paleo-connections between the Sun, climate, and culture. About 80 scientists attended this meeting. In addition to the many oral and poster presentations, attendees enjoyed a special dinner speaker who discussed the rich history of early inhabitants and the archeology of western Colorado. The meeting concluded with an optional field trip to the Mesa Verde National Park to view the Anasazi ruins that are a result of sudden culture changes influenced by severe droughts at about 1300 AD.

### Introduction

Solar activity, the Earth's climate, and human culture all undergo change. An increasing number of paleoclimate records, such as are found in ice-cores, ocean sediments, lake levels, and tree-rings, suggest a solar contribution to past climate change because many records correlate strongly with the Berillium-10 ( $^{10}\text{Be}$ ) and Carbon-14 ( $^{14}\text{C}$ ) cosmogenic isotopes. The cosmogenic isotopes are considered to be proxies of solar activity, because solar modulation of the heliosphere alters the flux of incoming galactic cosmic rays which produce the isotopes. Furthermore, comparisons of paleoclimate records with archeological evidence of past human cultures suggest that solar-driven climate change may have contributed to the prosperity and demise of various civilizations, found for example, in the Yucatan and East Africa.

The 2005 SORCE meeting focused on both the empirical evidence and physical processes that link the sun, climate, and culture in the distant past. This includes understanding the relationship between solar irradiance and cosmogenic isotopes, which are typically assumed to reflect changes in solar brightness since this energy modulation is a million times larger than that of cosmic rays themselves. The lack of global climate records makes it difficult to discern the spatial pattern of the apparent climate response to past solar variability, which can provide clues about possible mechanisms. Nevertheless, from assorted paleo evidence at equatorial, mid- and high-latitudes, sometimes in combination with more recent data sets, a number of processes have been suggested. These include changes in the location of the intertropical convergence zone and in various dynamical modes including the North Atlantic Oscillation, the El Niño Southern Oscillation (ENSO), and in the Hadley and Walker Circulations. Civilizations most susceptible to

solar-driven climate change appear to be those located in regions where rainfall and drought are especially vulnerable to changes in these climate variability modes and circulation patterns, emphasizing the need to understand the role of the hydrological cycle in the sun, climate, and culture connection.

Between special keynote speakers, the meeting was arranged into five sessions to address the meeting topic:

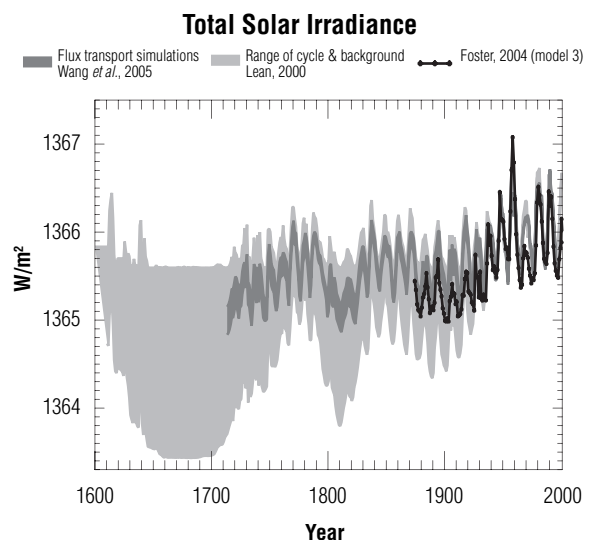
- SORCE Observations of Solar Radiation—New Science Results
- Reconstruction of Past Solar Irradiance and Modeled Climate Responses
- Evidence for Climate Responses to Solar Variability
- Interpreting the Solar and Climate Sources of Cosmogenic Isotope Variations and their Relationship to Solar Irradiance
- Linkages of Climate Cultural Responses and Solar Variability.

Most of the presentations are available on the SORCE Meeting website at [lasp.colorado.edu/sorcel/2005ScienceMeeting/](http://lasp.colorado.edu/sorcel/2005ScienceMeeting/).

### Wednesday, September 14, 2005

**Judith Lean** began the meeting with a keynote talk discussing the current understanding of secular changes

**Figure 1:** Estimates of solar irradiance variability over the past 400 years (from J. Lean).



in the Sun-Earth system. She introduced many of the workshop topics concerning solar variability and possible climate effects over the past 1000 years. As shown in **Figure 1**, Lean presented a new estimate of solar irradiance variability obtained from modeling the transport of magnetic flux on the Sun. For comparison, prior reconstructions have been based on variations in sun-like stars or on cosmogenic isotopes ( $^{14}\text{C}$  and  $^{10}\text{Be}$ ) and geomagnetic activity, which are sensitive to long-term variations in the heliosphere. The new estimates of long-term solar irradiance variations are smaller than prior estimates, having about one quarter of the increase from the Maunder Minimum (-1650) to the modern maximum (today's solar irradiance level).

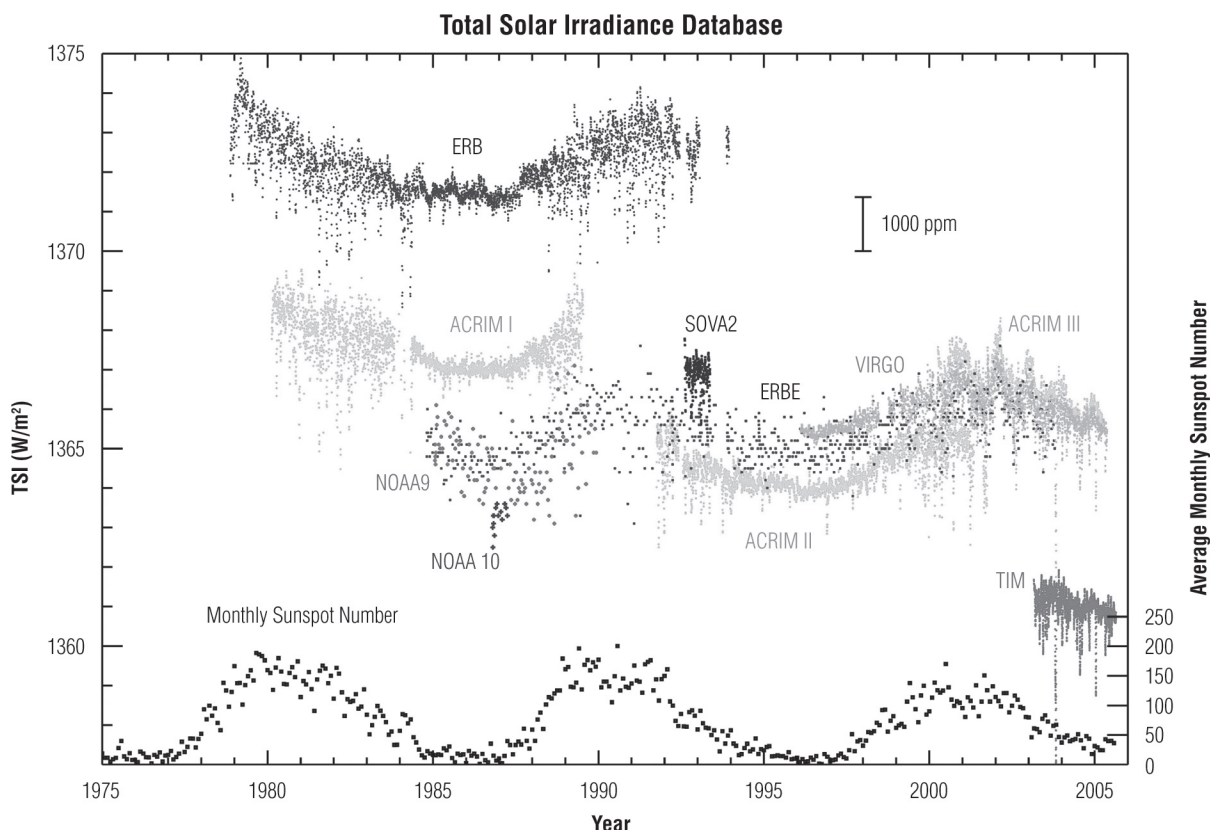
Session 1 took up the remainder of the morning, and highlighted the Solar Radiation and Climate Experiment (SORCE) observations of the total solar irradiance (TSI) and the spectral solar irradiance (SSI). **Gary Rottman** first gave an overview of the SORCE mission and some of its results. Rottman also discussed his retirement; the role of Principal Investigator has officially been transferred to Tom Woods at LASP. Tom has been the LASP Project Scientist for the SORCE mission.

**Greg Kopp** summarized results of the TSI observations by the SORCE Total Irradiance Monitor (TIM). He discussed TSI variations, including the first measurements of flares detected in the TSI time series, and

some of the issues concerning TIM's absolute value of total solar irradiance which is about  $5 \text{ W/m}^2$  lower than the previous measurements, as shown in **Figure 2**. A TSI Validation Workshop was held at NIST in July to begin to address this issue. **Joe Rice** discussed the workshop results later in the Wednesday morning session. Some of the conclusions of the TSI validation workshop are that the TSI uncertainties should be increased for most measurements and that instrumental corrections, such as aperture diffraction effects and scattered light off baffles, are not consistently applied by different instrument teams, and should be studied in more detail.

Other talks in the SORCE morning session addressed the spectral solar irradiance. **Jerry Harder** presented new results from the Spectral Irradiance Monitor (SIM) regarding solar variability from the near ultraviolet (NUV) near 300 nm, through the visible, and into the near infrared (NIR) near 2500 nm. Harder related the measured spectral variability to the modeled irradiance expected from the presence of solar features, such as sunspots and faculae, as identified from solar images. **Bill McClintock** presented the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) results of solar irradiance from the far ultraviolet (FUV) near 120 nm to the NUV. He showed that the SOLSTICE results from both the Upper Atmosphere Research Satellite (UARS) and SORCE are consistent within

**Figure 2:** Total solar irradiance (TSI) measurement record for 3 solar cycles (from G. Kopp).



their respective calibration uncertainty (accuracy) of about 5%. **Tom Woods** presented flare observations from the SORCE XUV Photometer System (XPS), compared with the TIM's TSI detection of the flares. Tom showed that the XUV radiation from 0.1-27 nm is about 30% of the TSI variation during large flares and that the TSI total energy from a flare is 110-150 times the total energy measured by the GOES X-Ray Sensor (XRS) in the 0.1-0.8 nm band (a factor of 10 higher than past studies have assumed).

The session concluded with a presentation by **Rodney Viereck** regarding NOAA's plans for future solar irradiance measurements. These plans include TSI and NUV-Visible-NIR SSI measurements from the series of NPOESS satellites, solar UV irradiance and the Mg II core-to-wing ratio (solar proxy for chromospheric variability) from the POES SBUV and NPOESS OMPS instruments, and extreme ultraviolet (EUV) and X-ray solar irradiance measurements from the series of GOES satellites.

Session 2, *Reconstructions of Past Solar Irradiance and Modeled Climate Responses*, took place on Wednesday afternoon. Two talks, by **Natalie Krivova** and **Sami Solanki**, discussed solar irradiance reconstructions. Natalie presented estimates of the total solar irradiance (TSI) and solar spectral irradiance (SSI) from the 4-component Spectral And Total Irradiance Reconstructions (SATIRE) model over the past 3 solar cycles. Sami presented a reconstruction of TSI and SSI variations from the present back to the Maunder Minimum. The other talks in this session addressed simulations of the climate response to solar forcing. **Caspar Ammann** showed that paleo-records suggest a solar influence on climate and that the NCAR Climate System Model (CSM 1.4) predicts global temperature changes of about 0.5 °C over the past 1000 years due to solar variations, consistent with the paleo temperature records. **Drew Shindell** presented results from the fully coupled chemistry-climate Goddard Institute for Space Studies (GISS) Model E, simulating temperature, winds, and photochemical responses, such as for ozone, to solar forcing. Two talks about the stratosphere-troposphere dynamical processes ended this session. Like Shindell, both **Kunihiko Kodera** and **Katja Matthes** stressed the importance of the solar UV irradiance variability that forces ozone changes in the stratosphere which dynamically couple to the troposphere. They showed data and general circulation model (GCM) predictions of temperature, winds, and ozone global and regional response to solar variability. Matthes showed the predicted temperature changes from lower solar irradiance values during the Maunder Minimum, noting that there is a slightly colder global temperature and much larger regional temperature changes (both hotter and colder).



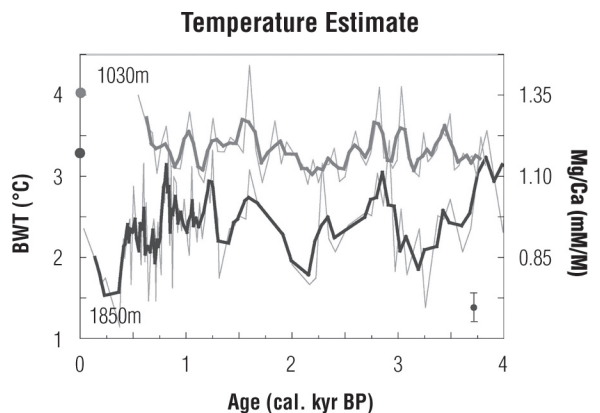
Session 2 speakers, Drew Shindell, Kunihiko Kodera, and Caspar Ammann (left to right), take time to discuss their research.

The poster session for the SORCE Science Meeting occupied the remaining part of Wednesday afternoon. **Dick White** opened the session with a summary of the 14 posters in the *Solar Variability* poster session. **Peter Pilewskie** followed, with a summary of the 5 posters in the *Sun-Climate* poster session. Lively discussions of the results in these posters ensued, several continuing long after the poster session into dinner. The posters are listed at the end of this article.

#### Thursday, September 15, 2005

**Peter deMenocal's** keynote talk commenced the second day of the meeting. Peter dedicated this morning session to **Gerard Bond**, who passed away this year. Well known for his innovative research involving ocean sediment analysis and results concerning paleoclimate changes, Gerard had attended the 2003 SORCE meeting and was hoping to also participate in the Durango meeting. DeMenocal presented an overview of the late Holocene solar and ocean circulation variability observed in the North Atlantic Ocean sediments. The sediment records indicate temperature variations of 1-2 °C that appear related to small solar variations over the past 3000 years. A probable mechanism for these changes is deep ocean convection changes in response to solar forcing. This

**Figure 3:** Temperature estimate from North Atlantic Ocean sediment records (from P. deMenocal).





Harry van Loon (left) and Sultan Hameed enjoy one of the meeting breaks.

mechanism also supports the observed ocean salinity changes (fresher during colder periods).

Session 3, *Evidence for Climate Responses to Solar Variability*, on Thursday morning comprised eight talks. A common theme during this session was the relationships of long-term regional climate proxies, especially those for drought and rainfall, with the cosmogenic isotope records of solar variability. It is important to note that regional changes are much more dramatic than the globally averaged changes. **Harry van Loon** presented compelling evidence for the impact of the solar cycle on Pacific Ocean circulation and temperature decadal changes. **Curt Stager** revisited a long-standing, sun-climate puzzle—that of the relationship between rainfall in East Africa at Lake Victoria and solar variability over the past century and past 1000 years. The variations are related to ENSO and Indian Ocean circulation changes, but their linkages with solar activity are intermittent (sometimes uncorrelated). Two other talks by **Subarna Bhattacharyya** and **Ashish Sinha** also showed correlations between solar variability and the Indian Ocean circulation changes and associated droughts and rainfall in India.

**Paul Mayewski** provided a longer term perspective in his discussion of the Greenland ice-core records of climate variations over the past 110,000 years. These climate variations indicate large temperature variations of about 20° C in Greenland prior to 10,000 years before present (BP). Mayewski showed that the temperature variations appear to be caused by significant changes in the polar circulation patterns, and that disruptions to Asian civilization occur during the coldest periods. He also presented instrumentally calibrated proxies for atmospheric circulation developed from Antarctic ice cores. Comparison with the <sup>10</sup>Be proxy of solar activity demonstrates significant correlations between solar variability and the strength of zonal winds forced via solar induced changes in stratospheric ozone. Further aspects of the hydrological cycle were the focus of the next two talks, namely, possible relationships between river levels (rainfall) and solar variations. **Charles Perry** presented

Mississippi River flow results over the past 140 years and showed how the Pacific Ocean heating and circulation pattern changes are a possible lagged driver of the rainfall that affects the Mississippi River flow. **Alexander Ruzmaikin** analyzed the Nile River flow records over the past 1400 years, relating these changes to solar variations at 11 years, 88 years, and 260 years. He also connected solar variability to changes in the Northern Annular Mode (NAO), affecting the Hadley circulation and thus the rainfall in Africa. Alexander showed support for the hypothesis that rainfall increases in equatorial Africa during periods of less solar irradiance (such as during the Maunder Minimum). **David Lund** presented the final talk in this session, showing that Gulf Stream salinity level increased during the Little Ice Age (LIA: 1200-1850 AD) and that this increase could be explained by the Inter-Tropical Convergence Zone (ITCZ) having southward migration in response to lower solar irradiance values.

The focus of the Thursday afternoon session, Session 4, was *Interpreting the Solar and Climate Sources of Cosmogenic Isotope Variations and their Relationship to Solar Irradiance*. The five talks in this session discussed the geomagnetic field and how the cosmic rays are modulated by geomagnetism as well as solar activity. The first two talks, by **Monika Korte** and **Cathy Constable**, provided overviews of the long-term and short-term changes of the geomagnetic field. There are significant long-term changes in the geomagnetic dipole moment.

The next three talks described how the cosmic rays are modulated, how this modulation affects the production of cosmogenic isotopes, and the implications for long-term climate changes of the cosmogenic isotope records. **Horst Fichtner** pointed out that the long-term temperature changes could be due to changes in the solar irradiance or cosmic rays (or both) and that these different forcings potentially could be isolated by examining the 22-year variations. The cosmic ray variations have a stronger 22-year cycle than the solar irradiance. He further showed that cloud, rainfall, and temperature data do have a 22-year signal, suggesting the importance of cosmic ray forcing on the climate. **Raimund Muscheler** re-emphasized the importance for the cosmogenic isotope production of both the geomagnetic field variations and the solar magnetic/particle modulation, driven by solar activity impacts on the heliosphere. He showed a reconstruction of solar irradiance for the past 1000 years assuming that the heliospheric modulation and solar irradiance changes are related. Muscheler also pointed out that the <sup>10</sup>Be isotope has more simple processes compared with the <sup>14</sup>C isotope processes, which are complicated by its interaction with the biosphere and oceans. The <sup>10</sup>Be and <sup>14</sup>C records over the past 12,000 years are very similar and indicate long-term solar variations. **Christy Field** presented results using the GISS Model E on how the

climate itself modulates the  $^{10}\text{Be}$  deposition, suggesting that the  $^{10}\text{Be}$  record may be expected to overestimate solar variations when used to model climate responses to solar forcing.

That evening, meeting participants enjoyed the Fort Lewis College's Center of Southwest Studies cultural history museum which hosted viewing and a reception. Later that evening, the group dined at the historical Strater Hotel. The dinner speaker, **Mark Varien**, presented a fascinating talk about the history of the Pueblo Indian settlements in the local area and how the historical ecology, e.g., drought, impacted their culture. Varien's talk was a great introduction for Friday's tour of Mesa Verde National Park.

#### Friday, September 16, 2005

In his keynote talk on Friday morning, **Scott Lehman**, also paid tribute to Gerard Bond, then discussed the responses of the Norwegian Sea to solar forcing. Scott introduced first the linear relationship between solar proxies and the  $\delta^{18}\text{O}$  isotope record in the ocean sediments, which is related to air temperature when it is deposited. He then showed longer term records over the past 10,000 years and discussed how the North Atlantic Oscillation (NAO) could be a mechanism for causing sea surface temperature (SST) fluctuations.

The topic of the remainder of the meeting, Session 5, was *Linkages of Climate Cultural Responses and Solar Variability*. The five talks in this session presented evidence for cultural changes plausibly related to climate changes associated with solar forcing. **Ray Bradley** first talked about possible secular changes in solar activity derived from the  $^{14}\text{C}$  record, then showed that glacier advances are correlated with lower solar activity, as is regional rainfall. Bradley presented a geographical synopsis of evidence supporting climate responses to solar variations. **Bas van Geel** talked about several different regional climate and culture changes during the past 10,000 years that are correlated with solar activity. In a graphic illustration of how the sun, climate, and culture may be connected, **Sultan Hameed** showed an increased frequency of peasant rebellions and cannibalism during severe droughts (as based on China's written records) and suggested that the fall of the Ming Dynasty in 1644 is probably linked to the severe drought in 1628-1643, which occurred during the Sun's Maunder Minimum. In an excellent demonstration of the impact of droughts on present-day society, **Connie Woodhouse** showed the importance of water-flow records for the Colorado River basin for State managers, and discussed how the 22-year drought periods in Colorado dominate the river flow and water resources in the area. **Joan Feynman** concluded the session with a talk about agriculture development—its history, driving factors for its development, and how the dramatic changes in

climate (solar activity) about 12,000 years ago might have enabled agricultural development.

To conclude the SORCE Meeting, **Dick White** and **Peter Pilewskie** provided brief overall summaries. White pointed out the success of the meeting in reviewing and discussing many of the interesting links between climate and solar activity and possible impacts on cultural changes, and in raising new questions and encouraging future collaborations. Pilewskie introduced the concept for the next SORCE Science Meeting, planned for the fall of 2006 on the topic of the many outstanding radiative energy issues of the Sun-Climate system relating to, for example, clouds, aerosols, solar radiation, and dynamical transport of energy. Everyone is welcome and details will be posted on the SORCE website as they become available: [lasp.colorado.edu/sorce](http://lasp.colorado.edu/sorce).

#### Poster Sessions

##### *Session 1. Solar Variability:*

*Connecting Inferred Solar Microvariability over the Past 200ky with Observed Microvariability of 582 Solar-Class Stars from the ESA Hipparcos Program*, by **Aden & Marjorie Meinel**, University of Arizona, Tucson and Jet Propulsion Laboratory, Pasadena, California and Santa Barbara, California

*What was the Probable State of the Solar Chromosphere and Corona during the Maunder Minimum?* by **Phil Judge**, High Altitude Observatory (HAO), National Center for Atmospheric Research, Boulder, Colorado

*Cyclic and Secular Activity Changes in Solar Analog Stars*, by **Jeffrey Hall**, Lowell Observatory, Flagstaff, Arizona

*Variability and Redundancy across the Solar Spectrum*, by **Peter Fox**, HAO/ESSL/National Center for Atmospheric Research, Boulder, Colorado

*Spectral Irradiance Modeling and Long-Term Trends*, by **Juan Fontenla**, Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder

*Accuracy of Solar Radius Determinations from Solar Eclipse Observations, and Comparison with SDS and SOHO Data*, by **David Dunham**, Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland

*Observing the Solar Photosphere from Space using the MDI and HMI Instruments*, by **Rock Bush**, Stanford University, California

*Empirical Orthogonal Function Analysis of Observed and Modeled Solar Spectral Irradiances*, by **Guoyong Wen**, Goddard Earth Sciences and Technology Center and NASA Goddard Space Flight Center

*The NOAA MgII Core-to-Wing Ratio*, by **Larry Puga**, NOAA, Space Environment Center, Boulder, Colorado

*Preliminary Estimate of the Mg II Index from 1932 to 1974*, by **Jeff Morrill**, Naval Research Laboratory, Washington, DC

*SORCE SOLSTICE High-Time Cadence Magnesium II Observations*, by **Marty Snow**, LASP, University of Colorado, Boulder

*Absolute Calibration of SORCE SOLSTICE*, by **Marty Snow**, LASP, University of Colorado, Boulder

*The LASP Interactive Solar Irradiance Database (LISIRD)*, by **Marty Snow**, LASP, University of Colorado, Boulder

*SORCE Data Processing and Data Products*, by **Chris Pankratz**, LASP, University of Colorado, Boulder

#### **Session 2. Sun-Climate:**

*A Climatological Spectral Study for Diagnosing the Solar 11-Year Signal in the Northern Hemisphere Atmosphere*, by

**Ming Chen**, Information Management Systems Group (IMSG) at NOAA/NESDIS, Camp Springs, Maryland

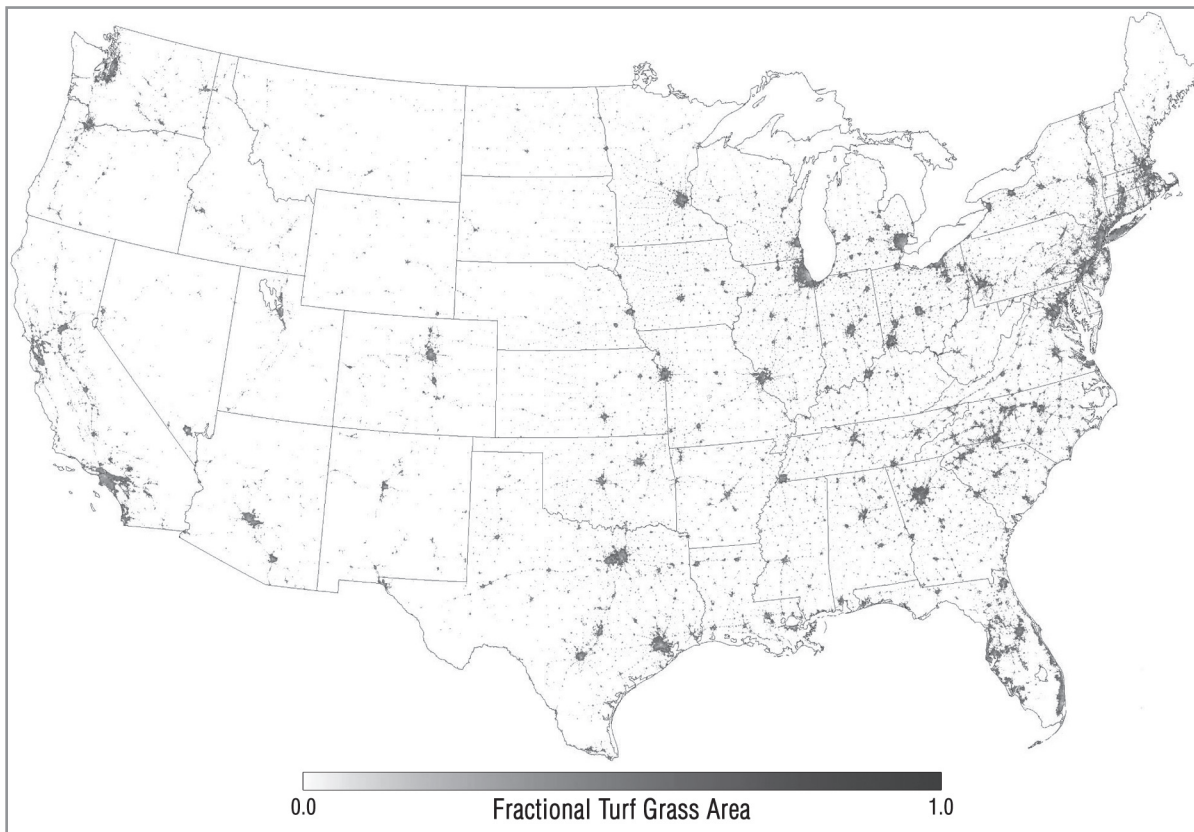
*The Fossil Record of UV-B in Juncus Seeds and the Relation with Climate Change*, by **Dan Yeloff**, University of Amsterdam, The Netherlands

*A Model for Investigating Sun-Climate Questions*, by **E. J. Zita**, Evergreen State College, Olympia, Washington

*Solar Variability, Climate, and Human Response: A view from the Southwest*, by **David Gregory** and **Fred Nials**, Center for Desert Archaeology, Pinetop, Arizona

*Connecting the Inverse Correlation between  $^{10}\text{Be}$  and GRIP Temperature and Snowfall Accumulation over the Past 200 Ky with Relevance to the Variation of  $^{10}\text{Be}$  during the past 80 Ky and to the 40-Ky BP Surge*, by **Aden & Marjorie Meinel**, University of Arizona, Tucson and Jet Propulsion Laboratory, Pasadena, California and Santa Barbara, California ■

Among the human-tailored landscapes that influence carbon and water cycles in America are lawns. This map shows satellite-derived estimates of the fractional turf grass (lawn) area across the United States. Areas where a large fraction of the land surface is lawn-covered are darker, while locations where the lawns cover a very small (or no) fraction of the land surface are lightest or white. The map shows how common lawns are across the country, despite a wide variability of climate and soils. The scientists who produced the map estimate that more surface area is devoted to lawns than to any other single irrigated crop in the country. Map courtesy Cristina Milesi, NASA Ames Research Center.



## Workshop on Ecological Modeling using NASA Multi-angle Remote Sensing

Mark Chopping, [chopping@pegasus.montclair.edu](mailto:chopping@pegasus.montclair.edu), Montclair State University

David J. Diner, [djd@jpl.nasa.gov](mailto:djd@jpl.nasa.gov), NASA Jet Propulsion Laboratory

A workshop on Ecological Modeling using NASA Multi-angle Remote Sensing was held on September 20, 2005, at the Marriott Hotel in Greenbelt Maryland, with 30 participants in attendance from a diverse set of institutions. An initiative of the Multi-angle Imaging SpectroRadiometer (MISR) project, the workshop was intended to provide remote-sensing scientists with details of ecosystem modelers' needs; and to acquaint modelers with current multiangle imaging capabilities, limitations and future possibilities. The goal was to facilitate the exchange of ideas between members of the ecological-modeling community and remote-sensing scientists familiar with multiangle imaging and associated techniques such as modeling canopy reflectance and the surface bidirectional reflectance distribution function (BRDF).

**David J. Diner** (MISR Principal Investigator, NASA/Jet Propulsion Laboratory [JPL]) and **John V. Martonchik** (MISR Co-Investigator, NASA/JPL) gave a concise but comprehensive overview of the MISR instrument capabilities, observational principles, and data products, focusing on MISR surface products. MISR observes the Earth at nine discrete along-track view angles between nadir and 70° off-nadir, in four spectral bands. Global data are routinely obtained with resolutions between 275 m and 1.1 km. Current standard surface products from MISR include atmospherically-corrected directional reflectances and albedos, leaf area index (LAI) and fractional absorbed photosynthetically active radiation (FPAR), using the multiangle information to supplant the conventional prescription of a known biome type, and parameters from a modified form of the semi-empirical Rahman-Pinty-Verstraete bidirectional reflectance function (MRPV). The parameters derived from the latter include  $k$ , an indicator of brightening or darkening from nadir to off-nadir angles, and  $b$ , a measure of fore-aft reflectance asymmetry. MISR's airborne counterpart, AirMISR, has been flown on NASA ER-2 aircraft over a number of forested sites, obtaining data with the same angular/spectral coverage as MISR, but with georectified spatial resolution of 27.5 m.

Subsequent presentations were divided into two categories: ecological modeling needs from remote sensing, and applications of MISR in assessing forest structure. Each talk was followed by questions and brief discussion, with much of the afternoon also devoted to discussion.

### Meeting Highlights

**Paul Moorcroft** (Harvard University) presented a detailed talk, *Using Remote Sensing Estimates of Forest Structure to Constrain Terrestrial Ecosystem Models*, covering recent developments in using forest structure estimates in terrestrial ecosystem modeling. Forest ecology is expressed through successional dynamics that depend on various forms of disturbance, e.g., regrowth, fire regimes, carbon in soils. The individual-based Ecosystem Demography (ED) model was shown to predict long-term (200-yr) trends in above-ground biomass well for tropical forest. Statistical mechanics can be used to operate ED at much larger, regional, scales and it has recently been modified (ED2) and used in a fully-fledged land-surface biophysics model, which incorporates the Regional Atmospheric Modeling System (RAMS). With this new constrained regional carbon cycle model, progress has been made in fitting to both short-term and long-term scenarios (expressed in terms of Carbon dynamics); the model incorporates and accommodates both fast processes and long-term vegetation dynamics. The ED2 Land Surface Model parameterizes the surface as a potentially heterogeneous mosaic of patches within which forest structure differs. NASA EOS remote sensing can provide phenology metrics from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor; forest structure measures from MISR would also be very useful in initializing and validating the model, especially outside the Northern hemisphere where forest inventories are far less complete.

**George Hurtt** (University of New Hampshire) gave a talk (*The ED Ecosystem and LM3 Land Surface Models*) which presented the results of research showing that from 1700-2000, 42-68% of the global land surface (excluding ice-covered areas) has been impacted by human activities; secondary land area increased by 10-44 million km<sup>2</sup>, of which about half is forested. Wood harvesting and shifting cultivation generated 70-90% of this secondary land with permanent agriculture change generating the remainder. Hurtt pointed out that terrestrial ecosystems are not in a *potential state*; the scientific challenge is to adequately characterize the land surface, and to develop the capability to project future land-surface dynamics. Direct measurement of contemporary conditions is available over some regions, e.g., forest inventories in northern temperate countries, but data are limited in spatial and temporal resolution and coverage. Land-use history reconstructions are rapidly advancing, but hampered by lack of relevant historical data. On the



other hand, advances in remote sensing of vegetation structural properties are promising but limited in terms of current resources. Ultimately, new remote-sensing methods are needed to characterize vegetation structure globally, requiring investment in remote-sensing capabilities, relevant ecosystem modeling, and field surveys.

Several of the presentations on retrieving forest structural parameters, e.g., canopy height, leaf area index, biomass, cover, included results from experiments combining multiangle remote sensing with lidar (**Ranson, Ni-Meister**) and MODIS (**Braswell**). Lidar data are providing information on forest structure and are being used by ecologists to estimate stand-age-structure and biomass (carbon), and to initialize and validate height-structured ecosystem models such as the Ecosystem Demography (ED) model. Above ground biomass estimates ( $\text{kg C/m}^2$ ) from field measurements, lidar, and ED were shown to be very similar for a tropical forest site (**Hurt**). However unlike multiangle data from MISR, lidar data are not acquired over large areas: a major question is, therefore, how to scale up to the regional and global levels?

**Jon Ranson** (NASA/Goddard Space Flight Center [GSFC]) presented a talk entitled *Towards Synergistic use of Satellite Multiangle and Lidar Data for Assessing Forest Structure*, describing the successful synergistic use of data from AirMISR together with those from the NASA Laser Vegetation Imaging Sensor (LVIS); and those from MISR on the Terra satellite with those from Geoscience Laser Altimeter System (GLAS) on the Ice, Cloud and land Elevation Satellite (ICESat). Although the lidars provide only a sparse spatial sampling, these data are appropriate for calibrating multi-angle data with more complete spatio-temporal coverage such as those from MISR. For study sites in Maine and Maryland, the lidar data were used to *train* the multi-angle imaging retrievals in a neural net. Following the training, a high degree of correlation between canopy heights predicted from the imager data and the more-direct lidar profiles was obtained. This preliminary work indicates that a dense network of forest heights from lidar can be used to develop a method for estimating heights from using multi-angle data.

**Wenge Ni-Meister** (Hunter College, City University of New York [CUNY]) gave a presentation entitled *Integrating AirMISR and Lidar for Forest Structure Extraction*. She has been using the Geometric Optical Radiative Transfer (GORT) model to understand the sensitivities of optical multi-angle and lidar data to canopy structure. A particular area of interest is in understanding the effects of canopy clumping on lidar signals, and the use of passive BRDF and its spatial variance in the detection of clumping. AirMISR data were used to show sensitivity to clumping in multi-angle data. Correction for atmospheric effects is important.

**Xue Liu** (George Mason University) presented a talk entitled *MISR Multi-angle Remote Sensing of Forest for Carbon: Experiments and Preliminary Results*. Liu has been studying a temperate deciduous forest in northern Virginia/southern Maryland, using MISR data for scene classification. Accuracy in forest-extent data improved from 53%-74% when multi-angle information from several view angles were combined. A new area of research is using MISR for estimation of forest age and early regeneration stages. Preliminary results indicating discrimination of areas younger than 20 years from those between 20 and 40 years old were shown.

**Jing Chen** (University of Toronto) gave a talk on *Applications of POLDER and MISR for Vegetation Structure*. The Polarization and Directionality of Earth's Reflectance sensor (POLDER) multi-angle observations in the principal scattering plane were shown to correlate well with canopy clumping index, a parameter that multiplies LAI in describing photon transmission probability through a canopy. Due to its smaller cross-track field-of-view, MISR does not observe as close to the principal plane as POLDER, but has the advantage of higher spatial resolution, which is important for retrieval of 3-D canopy structure. Recent work has been on the use of MISR data for separating background reflectance from the combined canopy-surface system, which is important for improving estimates of LAI over forests.

Workshop participants also discussed methods for retrieval of canopy structural attributes using multi-angle data sets. The most successful methods to date seem to be empirical or semi-empirical, e.g., regression, neural networks, or combinations of empirical relationships in physical models. **Rob Braswell** (University of New Hampshire) presented a talk (*Combined use of Physical and Empirical Modeling*) on multi-angle-multispectral terrestrial applications in which he described a top-down, multivariate approach to exploiting multi-angle data in which MISR channels are treated as independent variables. **Mark Chopping** (Montclair State University) demonstrated how the isotropic, geometric, and volume scattering kernel weights obtained via adjustment of a Li-Ross kernel-driven model against MISR data can be exploited to semi-empirically estimate the angular response of the soil-understory complex. This is a prerequisite for successful application of geometric-optical and hybrid geometric-optical/radiative transfer models where the background makes an important contribution in the total signal.

**Nancy Ritchey** (NASA/Langley Research Center [LaRC]) gave a talk on obtaining MISR data products and provided information on available On-Line Visualization Tools. **Charles Thompson** and **Brian Rheingans** (both of NASA/JPL) demonstrated a new version of the *mISR\_view* display and analysis software tool,

which makes it much easier to manipulate, reproject, subset, and transform MISR data sets. This software package is available free of charge at [www.openchannelfoundation.org/projects/misr\\_view\\_5.2](http://www.openchannelfoundation.org/projects/misr_view_5.2), and uses the Interactive Data Language (IDL).

### Discussion

In the afternoon, breakout groups (each headed by an ecologist) discussed the following key questions aimed at ensuring that the workshop could identify next steps:

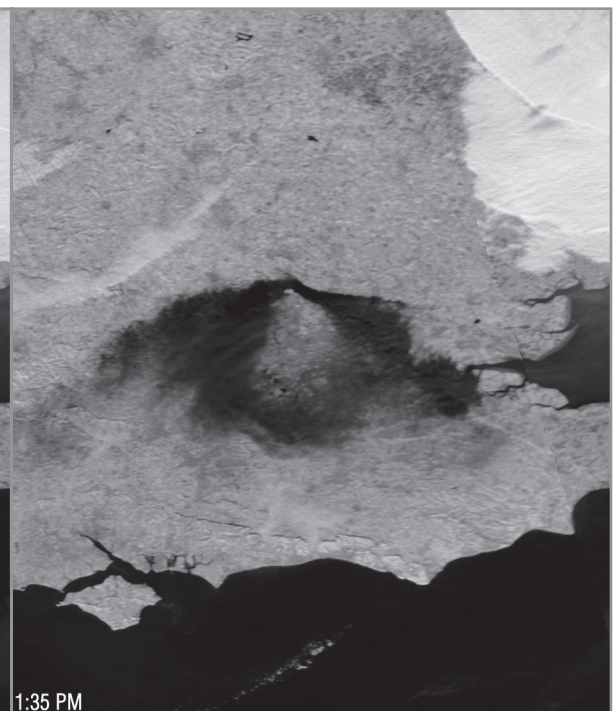
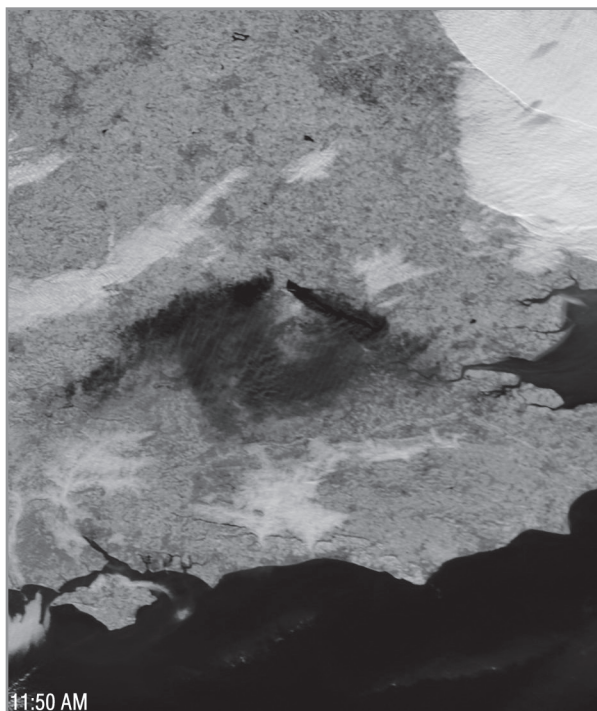
- What are the key science questions that terrestrial ecology is facing?
- To what extent is *structure* a key element of answering these questions? How can we focus the general concept of *structure* on specific parameters required by modelers?
- How can MISR data, either alone or in synergy with other measurements, help meet these requirements?
- Are there any particular impediments to MISR data usage that need to be overcome?

### Outcomes from the Meeting

The modelers were very interested and excited by the potential MISR capabilities and the MISR/lidar synergies that were presented at the meeting. In addition to LAI, an existing standard MISR product with capability to deal with situations where single-angle approaches saturate, the participants expressed direct interest in time series of other structural parameters, including:

- canopy clumping index (defined from the expression for the probability of light transmittance at angle  $\theta$ , as  $p(\theta) = \exp[-G(\theta) \cdot LAI \cdot \Omega / \cos(\theta)]$ , where  $G(\theta)$  is the mean projection of leaf normals and  $\Omega$  is the clumping index);
- tree height;
- canopy roughness (variance in height);
- basal area;
- tree density;
- crown size and shape;
- above-ground biomass;
- detection of subcanopy changes, e.g., thinning by selective logging.

Continuation of the dialog initiated at this meeting will focus on several key issues. First, given the empirical results shown, it is critically important to develop a physical understanding of the high correlation observed between multi-angle reflectances and lidar canopy heights. Second, further development of multi-angle retrieval algorithms to establish the range of determinable parameters of interest to the modeling community is needed. Third, community focus on multisensor data sets over well-studied areas, such as experimental forests, is necessary to understand the strengths and limitations of different remote sensing approaches and inversion methods, and how to potentially use them in combination. The third issue stimulated participants to propose a longer (three to five day) follow-up workshop, which will take place in the Spring of 2006. ■



## EOS Science Calendar 2006

### February 21-23

Community Workshop on Air Quality Remote Sensing from Space: Defining an Optimum Observing Strategy, Boulder, CO. URL: [www.acd.ucar.edu/Meetings/Air\\_Quality\\_Remote\\_Sensing](http://www.acd.ucar.edu/Meetings/Air_Quality_Remote_Sensing). Contact: David Edwards, [edwards@ucar.edu](mailto:edwards@ucar.edu).

### March 20

Workshop on Exploring and Using Multi-angle Imaging SpectroRadiometer (MISR) Data (part of the Fourth International Workshop on Multi-angular Measurements and Models [IWMMM-4]), Sydney, Australia. Contact: Nancy Ritchey, [n.a.ritchey@larc.nasa.gov](mailto:n.a.ritchey@larc.nasa.gov). URL: [eosweb.larc.nasa.gov/PRODOCS/misr/workshop/](http://eosweb.larc.nasa.gov/PRODOCS/misr/workshop/).

## Global Change Calendar 2006

### January 29-February 2

American Meteorological Society (AMS) 86<sup>th</sup> Annual Meeting, Atlanta, GA. URL: [www.ametsoc.org/meet/annual/index.html](http://www.ametsoc.org/meet/annual/index.html).

### March 9-10

Asia GIS 2006 International Conference, Universiti Teknologi Malaysia (UTM) Skudai, Johor, Malaysia. Call for Papers. URL: [www.utm.my/asiagis/](http://www.utm.my/asiagis/)

### March 20-24

4<sup>th</sup> International Workshop on Multiangular Measurements and Models (IWMMM-4), Sydney, Australia. Call for Papers. URL: [www.eoc.csiro.au/iwmmm-4/](http://www.eoc.csiro.au/iwmmm-4/).

### April 2-7

The European Geosciences Union (EGU) General Assembly, Vienna, Italy. URL: [meetings.copernicus.org/egu2006/](http://meetings.copernicus.org/egu2006/).

### July 3-6

ISPRS Commission I Symposium, Paris, France. Call for Papers. Email: [isprs2006@colloquium.fr](mailto:isprs2006@colloquium.fr) URL: [www.colloquium.fr/sfpt2006](http://www.colloquium.fr/sfpt2006).

### July 12-14

4<sup>th</sup> IEEE Workshop on Sensor Array and Multi-Channel Processing (SAM), Westin Hotel, Waltham, MA. URL: [www.sam2006.org](http://www.sam2006.org). Call for presentations, due February 1, 2006.

### August 13-17

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

### September 25-29

2nd International Symposium on the Recent Advances in Quantitative Remote Sensing, Torrent, Spain. URL: [www.uv.es/raqrs/index.htm](http://www.uv.es/raqrs/index.htm). Abstracts due February 15, 2006: [sobrino@uv.es](mailto:sobrino@uv.es).

◀ Sunday, December 11, 2005, was a day without sun for many Londoners. At about 6 a.m. local time, an explosion rocked a fuel depot in Hertfordshire, approximately 40 kilometers (25 miles) north of London. The ensuing oil fire sent thick clouds of sun-blocking black smoke billowing over London and South England. By 11:50 a.m., when the Moderate Resolution Imaging Spectroradiometer (MODIS) flew over on NASA's Terra satellite, the smoke had fanned south over tens of kilometers. London, normally a large cement-colored circle on the landscape, was not even visible beneath the smoke. Nearly three hours later when Aqua MODIS flew over, the fire was still burning, and the smoke had spread still farther. NASA images courtesy the MODIS Rapid Response Team at NASA GSFC.

▶ Lying about 200 kilometers (124 miles) off the southeastern coast of Australia is the island state of Tasmania. Tasmania was probably connected to Australia until 10,000 years ago, when rising sea levels at the end of the last Ice Age cut it off from the continent. Before this happened, a wide range of species managed to populate Tasmania. The relatively small island is home to a surprising number of plants and animals. Its vegetation ranges from temperature rainforests to dry coastal areas to alpine shrubs. Besides the Tasmanian devil, wildlife includes wombats, echidnas, and platypuses. More than 20 percent of Tasmania has been listed with United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a World Heritage Area. NASA image courtesy Jeff Schmaltz, MODIS Land Rapid Response Team at NASA GSFC.





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