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The Earth Observer

Editor's Corner

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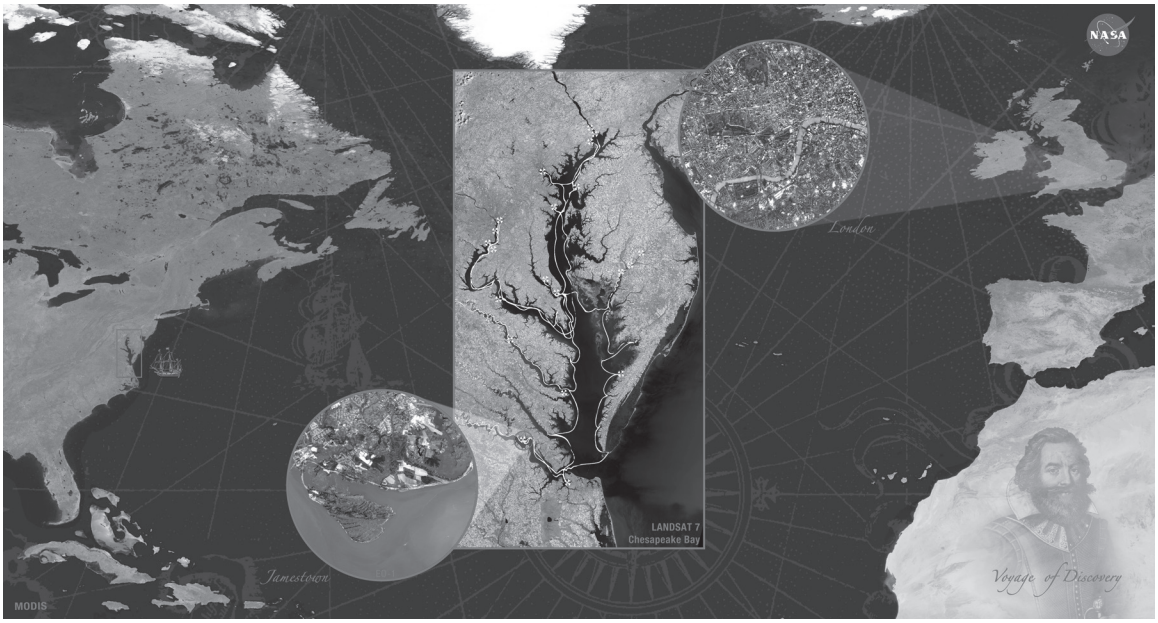
I am pleased to announce that the Aeronomy of Ice in the Mesosphere (AIM) mission is underway. AIM launched into orbit onboard an Orbital Sciences Pegasus XL rocket from Vandenberg Air Force Base in California on April 25, at 1:26 p.m. PDT. Launch operations ran smoothly with no technical or weather issues causing concern. AIM is a two-year mission to explore mysterious ice clouds that dot the edge of space in Earth's polar regions. These clouds have grown brighter and more prevalent in recent years and some scientists suggest that changes in these clouds may be the result of climate change. With the successful launch of AIM, Hampton University, Hampton, VA becomes the first historically black college and university to lead a NASA satellite mission. **James M. Russell, III**, Professor and Co-director of Hampton's Center for Atmospheric Sciences, is Principal Investigator (PI) for AIM. I extend my congratulations to Russell and to all who were involved in the launch. For the latest mission news, visit: *www.nasa.gov/mission_pages/aim/index.html.*

I am also very happy to report that NASA and NOAA have announced a plan to restore a key ozone layer climate sensor to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program.

continued on page 2

Her Majesty Queen Elizabeth II recently visited Goddard as part of her visit to America to commemorate the 400th anniversary of the establishment of the Jamestown Colony in Virginia. This poster (presented to the queen during her visit) uses data from three of NASA's Earth imaging sensors to celebrate the Virginia Company's long journey from London to Jamestown, and Captain John Smith's exploration of the Chesapeake Bay. A cloud-free image showing the North Atlantic Ocean, eastern North America, and western Europe and Africa, features Moderate Resolution Imaging Spectroradiometer (MODIS) data captured in July 2004, and gives a sense of the expansive portion of Earth that Smith and his cohort traversed in 1607. A Landsat 7 Enhanced Thematic Mapper Plus (ETM+) image of the Chesapeake Bay region is featured in the center. The white line demarks the path of Captain Smith's Chesapeake expedition. The small circle on the upper right of the bay image features an Earth Observing-1 (EO-1) Advanced Land Imager (ALI) image of central London acquired on February 14, 2001. The opposite circle shows a corresponding image of Jamestown acquired on April 3, 2007. The rhumb lines across the Atlantic Ocean and the engraving of Captain Smith over Africa are taken from Smith's 1616 map of New England, the first published map to name America's northeastern seaboard. A small image of the *Susan Constant*, the largest of the three Virginia Company ships, can be found near the Chesapeake Bay on the MODIS image.



In This Issue

The Ozone Mapping and Profiler Suite (OMPS) Limb will be returned to NPOESS Preparatory Project (NPP) satellite set to launch in 2009. NOAA and NASA have agreed to share equally the cost to restore the OMPS Limb to the NPP spacecraft. The OMPS Limb will measure the vertical distribution of ozone and complements existing NPOESS systems.

Restoring the OMPS Limb sensor directly addresses one of the recommendations of the recently released National Research Council's report *Earth Science Applications from Space: National Imperatives for the Next Decade and Beyond* discussed previously in the editorial of the March/April 2007 issue of *The Earth Observer,* [Volume 19, Issue 2, p.1].

"Having the OMPS Limb will give scientists a more complete picture of the content and distribution of gases in the atmosphere, and whether that distribution is good or bad," said retired Navy Vice Admiral **Conrad C. Lautenbacher, Jr.**, Ph.D., Undersecretary of Commerce for Oceans and Atmosphere, and NOAA Administrator. *"NOAA is committed to working with the scientific community to address their climate and other satellite observation requirements. This is a great step in that direction."*

"This sensor will allow us to move forward with the next generation of technology for weather and climate prediction," NASA Administrator **Michael Griffin** added.

In addition to this news, three members of NASA's Afternoon or *A-Train* satellite constellation recently celebrated milestones. April 28 marks the first anniversary for the CloudSat and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) missions, and May 4 marks the fifth anniversary of the launch of Aqua. The *A-Train* operates as a virtual platform in space with cooperation manifest between the missions, and integration of data from the various satellites' instruments as a vital goal.

CloudSat seeks to overcome shortcomings in the treatment of cloud processes in climate and weather forecast models, and provide the first global survey of large-scale and seasonal variations of cloud vertical structure and frequency of occurrence. CALIPSO seeks to help scientists answer significant questions, and provide new information concerning the effects of aerosols (airborne particles) and thin clouds on changes in Earth's climate. For more information on the first year of CloudSat and CALIPSO, please refer to the article on page 7 of this issue; URLs for CloudSat and CALIPSO respectively are *cloudsat.atmos.colostate.edu*, and *www-calipso.larc.nasa.gov*.

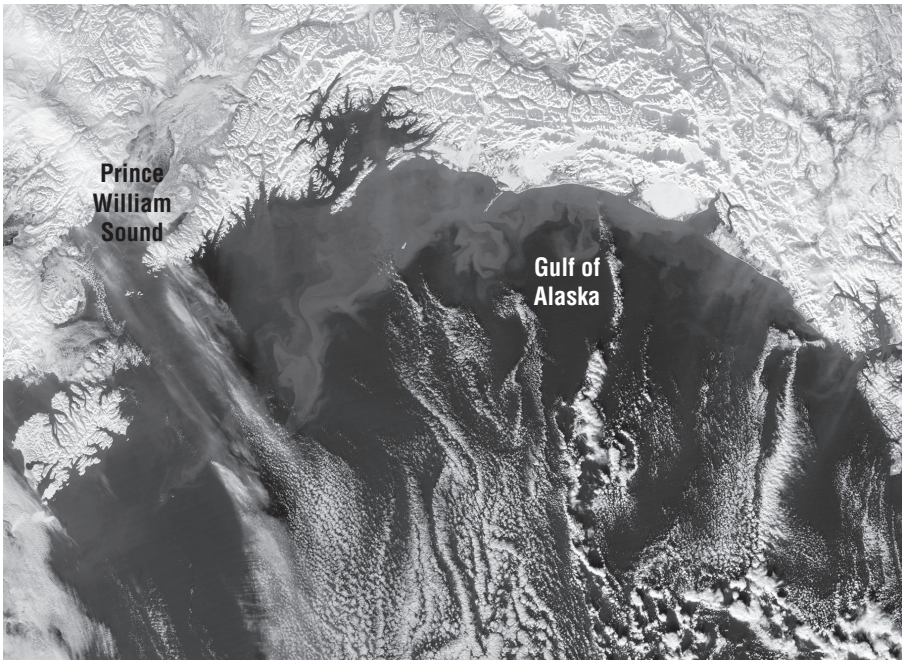
Aqua, Latin for water, is a NASA Earth Science satellite mission named for the large amount of information that it collects about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Additional variables also being measured by Aqua include radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures. Equipped with six state-of-the-art instruments (five of which are still operational at this time) data from the Aqua mission continues to advance our understanding of such phenomena as global precipitation, evaporation, and the cycling of water. This information helps scientists all over the world to better understand the Earth's water cycle and determine if the water cycle is accelerating as a result of climate change. For more details on the Aqua mission please see: *aqua.nasa.gov*.

My congratulations go out to the **Graeme Stephens** [Colorado State University—*CloudSat PI*], **David Winkler** [Langley Research Center—*CALIPSO PI*], and **Claire Parkinson** [Goddard Space Flight Center—*Aqua Project Scientist*] as well as to all the Aqua instrument PIs, and everyone else who has played a role in making these three missions a success. Keep up the good work!

I am also pleased to report that **Lars Peter Riishojgaard**, currently the leader of the Satellite Data Group in the Global Modeling and Assimilation Office (GMAO) at the NASA Goddard Space Flight Center, has been appointed Acting Director of the NASA–NOAA–Department of Defense Joint Center for Satellite Data Assimilation. Riishojgaard replaces John Le Marshall, who returned to the Australian Bureau of Meteorology in January. Louis Uccellini, Director, NOAA National Centers for Environmental Prediction, and Chair, JCSDA Management Oversight Board, made the announcement.

Riishojgaard has primary interests in data assimilation methodology, societal impact of weather and weather prediction, and the role of observational data and satellite systems in remote sensing. He received an M.S. in geophysics in 1989 and a Ph.D. in geophysics in 1992, both from the University of Copenhagen. Riishojgaard first came to the Data Assimilation Office (DAO) at Goddard in 1995 as a Universities Space Research Association Visiting Fellow. After a brief stint at the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), he returned to DAO to lead the development of its analysis system, and has been a scientist in its successor organization, the GMAO, since 2003. He has also served as the NASA Deputy Director of the JCSDA since 2002. I congratulate Riishojgaard and wish him success in his new position.

Lastly, on May 8, Her Majesty Queen Elizabeth II and the Duke of Edinburgh made a historic visit to Goddard Space Flight Center. The royal couple came to America to participate in the 400th anniversary of the establishment of the Jamestown Colony in Virginia, and the tour of Goddard occurred near the end of the visit. While at Goddard Her Majesty visited Mission Control for the International Space Station and NASA astronaut **Michael Foale** and NASA Administrator **Mike Griffin** hosted the queen and introduced her to the *Expedition 15* crew members as they orbited the Earth. From there the queen attended a welcome ceremony at the Building 8 Auditorium. During the ceremony, Griffin and Goddard Center Director **Ed Weiler** welcomed the queen, and House Majority Leader **Steny H. Hoyer** (D–MD) and Senator **Barbara Mikulski** (D–MD) presented the queen with a framed montage of images taken from the Hubble Space Telescope. Later, the queen visited the Goddard Visitor's Center and viewed several exhibits, including the *Science on a Sphere* display of global Earth science datasets. While there NASA Deputy Associate Administrator for Science, **Colleen Hartman**, presented Her Majesty with a framed image that commemorates the 400th anniversary of John Smith's exploration of Jamestown by using three of NASA Goddard's Earth imaging sensors (MODIS, Landsat 7 ETM+ and EO-1) to tell the story of the expansive portion of the Earth that he traversed. ■



The winter-white Alaska shoreline provides a vivid contrast to the swirls in the black waters of the Gulf of Alaska. The swirls are caused by sediment, ground into fine powder by mountain glaciers and carried into the Gulf of Mexico. The largest contributor of sediment shown in this photo-like image is the Copper River, immediately east of Prince William Sound. A dense bloom of *phytoplankton*—tiny, surface-dwelling plants that thrive in cool, nutrient laden waters—may also contribute to the swirly patterns. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured this image on January 7, 2007. For more information and the color image see *earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17526*. **Credit:** NASA Earth Observatory and MODIS Rapid Response Team.

QuikSCAT Shows Rough Seas/Atmospheric Conditions at Time of Two Java Sea Disasters

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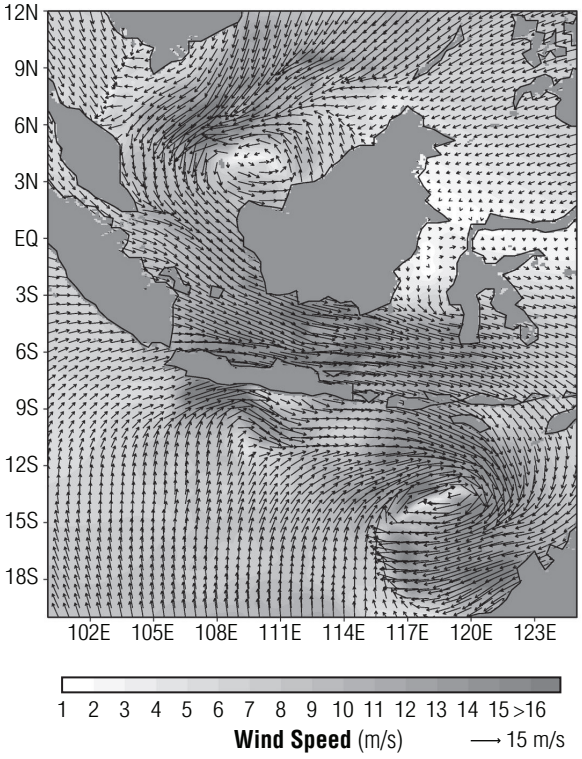
A ferry carrying more than 600 passengers sank in the Java Sea between the islands of Java and Borneo just before midnight on December 29, 2006, during high winds and rough seas. On January 1, 2007, a plane carrying more than 100 people crashed on its flight over the Java Sea; high winds and turbulent weather are being investigated as possible causes. The origin of surges of deadly winds in this usually relatively calm region is poorly monitored and understood. However, ocean winds data from NASA's Quick Scatterometer (QuikSCAT) satellite show potential for helping alleviate such deficiencies.

Data obtained from QuikSCAT on December 30 and January 1 shed new insights into the atmospheric conditions at the time of these incidents. QuikSCAT data are available in near real-time to operational weather forecasting agencies around the world. The data from December 30 and January 1 shows that the strong winds in the Java Sea originated from the surge of a strong winter monsoon from the Asian continent. The monsoon winds blew south across the South China Sea and deflected eastward after they crossed the equator due to the rotation of Earth. The winds strengthened as they were channeled through the land masses of Indonesia. The winds in the Java Sea remained strong through January 1, 2007. Associated with the easterly winds, QuikSCAT also observed twin cyclones (a counter-clockwise circulation in the Northern Hemisphere and a clockwise circulation in the Southern Hemisphere). The stronger one was south of the equator (summer hemisphere) between Java and Australia, and a weaker one was north of the equator (winter hemisphere) west of Borneo. In the image from January 1, the different shades of grey denote different wind speeds, with darker shades of grey representing stronger winds. Black arrows are wind vectors showing both direction and speed.



A QuikSCAT image from December 30 and January 1 shows the wind patterns in and around the Java Sea at the time of the ferry disaster and plane crash. Notice the two cyclones (upper left and lower right) rotating in opposite directions and the convergence of winds around the Java Sea.

The large-scale, broad, and simultaneous observations by QuikSCAT make it possible to put the local weather into the context of the large-scale circulation, and confirm one of the assumptions that links the cold surge of the Asian monsoon with tropical cyclones in the western Pacific —e.g., Chang et al. 2003.

QuikSCAT, managed by the Jet Propulsion Laboratory (JPL), measures ocean surface wind stress by sending radar pulses to the surface and measuring the strength of the signals returned.

QuikSCAT Background

NASA's QuikSCAT spacecraft was launched from Vandenberg Air Force Base, CA on June 19, 1999. QuikSCAT carries the SeaWinds scatterometer, a specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over the Earth's oceans.

JPL manages QuikSCAT for NASA's Science Mission Directorate. JPL also built the SeaWinds radar instrument and is providing ground science processing systems. NASA's Goddard Space Flight Center managed development of the satellite, designed and built by Ball Aerospace & Technologies Corp. The National Oceanic and Atmospheric Administration has contributed support to ground systems processing and related activities.

For more information about QuikSCAT, visit: *winds.jpl.nasa.gov/missions/quikscat/index.cfm*

Reference

Chang, C.-P., C.-H. Liu, and H.-C. Kuo, 2003: Typhoon Vamei: an equatorial tropical cyclone formation. *Geophys. Res. Lett.*, **30**(3), 1150: doi:10.1029/2002GL016365.

NASA Finds Arctic Replenished Very Little Thick Sea Ice in 2005

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A new NASA study has found that in 2005 the Arctic replaced very little of the thick sea ice it normally loses and replenishes each year. Replenishment of this thick, perennial sea ice each year is essential to the maintenance and stability of the Arctic summer ice cover.

The findings complement a NASA study released in fall 2006 that found a 14% drop in this perennial ice between 2004 and 2005. The lack of replenishment suggests that the decline may continue in the near future.

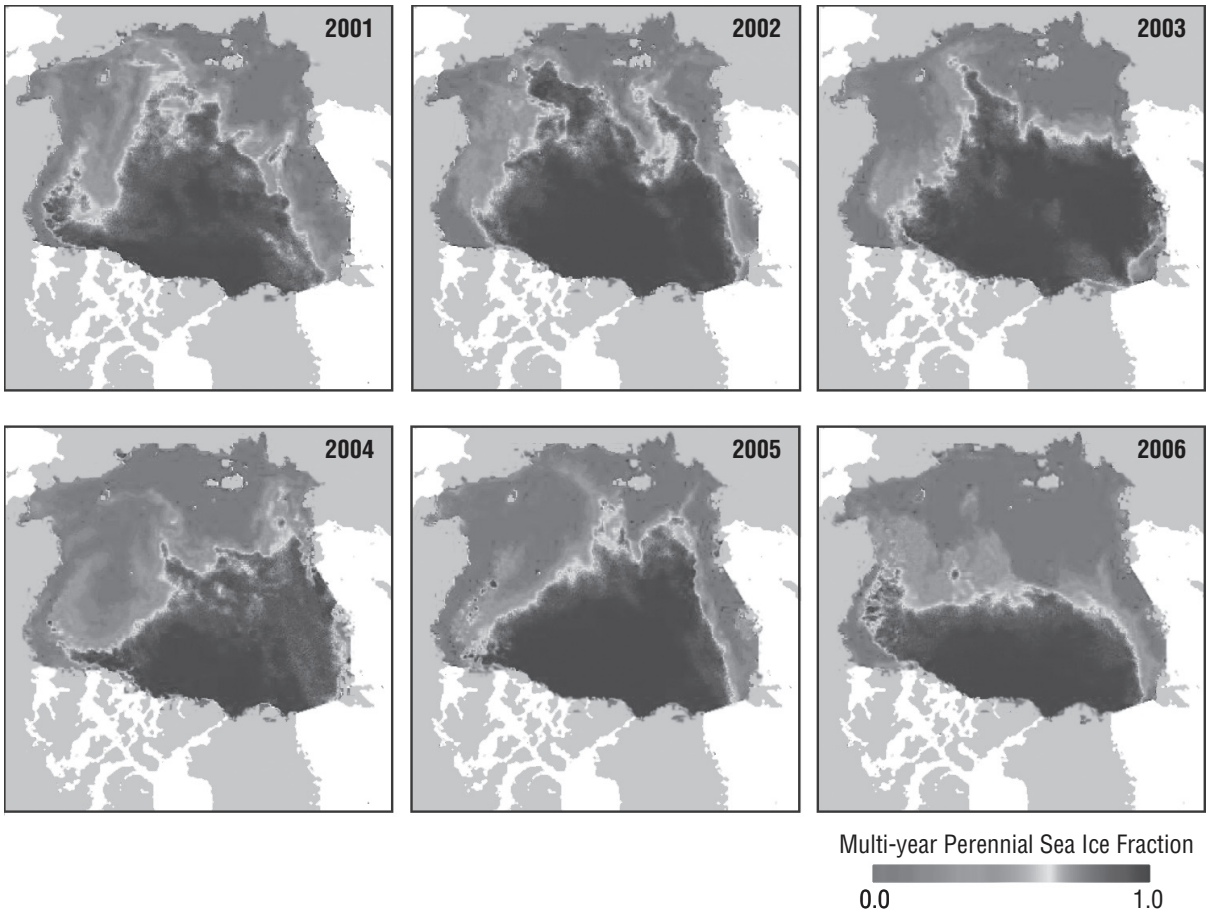
Perennial ice coverage fluctuates seasonally for two reasons: summer melting and the transport of ice out of the Arctic. When perennial ice, which is 3 m (10 ft) or more thick, is lost in these ways, new, thinner, first-year seasonal ice typically replaces it. Some of this seasonal ice melts the following summer, and some is thick enough to survive and replenish the perennial ice cover.

"Recent studies indicate Arctic perennial ice is declining 7–10% each decade," explained **Ron Kwok** of NASA's Jet Propulsion Laboratory, CA. "Our study gives the first reliable estimates of how perennial ice replenishment varies each year at the end of summer. The amount of first-year ice that survives the summer directly influences how thick the ice cover will be at the start of the next melt season."

Using satellite data from NASA's QuikSCAT and other data, Kwok studied six annual cycles of Arctic perennial ice coverage from 2000 to 2006. The scatterometer instrument on QuikSCAT sends radar pulses to the surface of the ice and measures the echoed radar pulses bounced back to the satellite. These measurements allow scientists to differentiate the seasonal ice from the older, perennial ice.

Kwok found that after the 2005 summer melt, only about 4% of the nearly 2.5 km^2 (965,000 mi^2) of thin, seasonal ice that formed the previous winter

Shown here are the measurements of perennial sea ice coverage from QuikSCAT for the past six years. Measurements of Arctic perennial sea ice coverage (shown in darkest shades) in winter 2006 were 14% less than in winter 2005. **Credit:** NASA/JPL



survived the summer and replenished the perennial ice cover. That was the smallest replenishment seen in the study. As a result, perennial ice coverage in January 2006 was about 14% smaller than the previous January.

Kwok examined how movement of ice out of the Arctic affected the replenishment of perennial sea ice in 2005. That year, the typically small amount of ice that moves out of the Arctic in summer was unusually high—about 7% of the perennial ice coverage area. Kwok said the high amount was due to unusual wind conditions at Fram Strait, an Arctic passage between the northeast coast of Greenland and Svalbard, Norway. Troughs of low atmospheric pressure in the Greenland and Barents/Norwegian Seas on both sides of Fram Strait created winds that pushed ice out of the Arctic at an increased rate.

The effects of ice movement out of the Arctic depend on the season. When ice moves out of the Arctic in the summer, it leaves behind an ocean that does not refreeze. This, in turn, increases ocean heating and leads to additional thinning of the ice cover.

These findings suggest that the greater the number of freezing temperature days during the prior season, the thicker the ice cover, and the better its chances of surviving the next summer's melt. "The winters and summers before fall 2005 were unusually warm," Kwok said. "The low replenishment seen in 2005 is potentially a cumulative effect of these trends."

Kwok also examined the 2000-2006 temperature records within the context of longer-term temperature records dating back to 1958. He found a gradual warming trend in the first 30 years, which accelerated after the mid-1980s. "The record doesn't show any hint of recovery from these trends," he stated. "If the correlations between replenishment area and numbers of freezing and melting temperature days hold long term, its expected the perennial ice coverage will continue to decline."

Kwok points to a possible trigger for the declining perennial ice cover. In the early 1990s, variations in the North Atlantic Oscillation, a large-scale atmospheric seesaw that affects how air circulates over the Atlantic Ocean, were linked to a large increase in Arctic ice export. It appears the ice cover has not yet recovered from these variations.

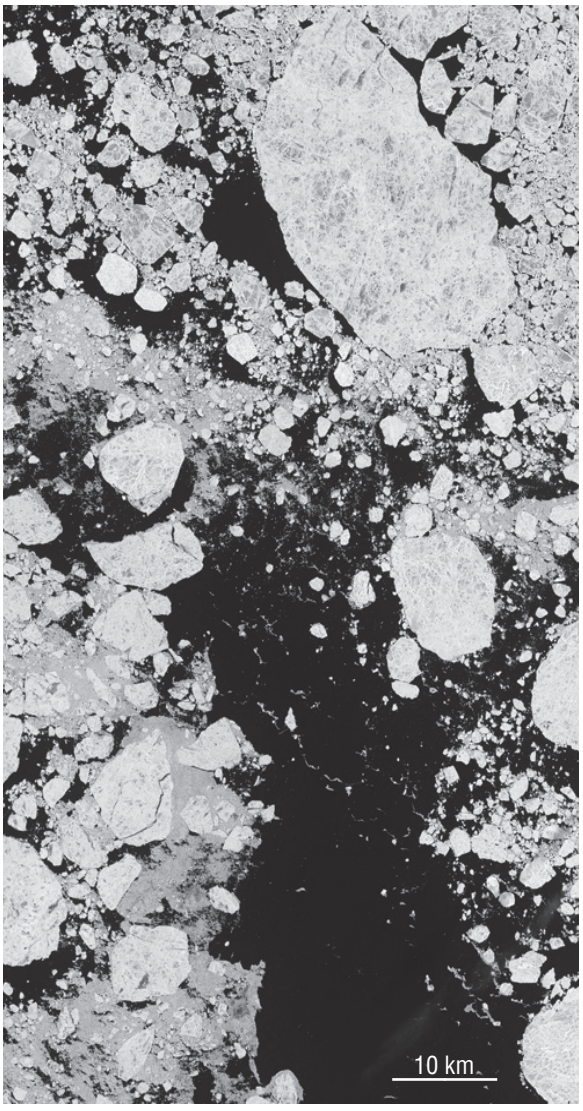
"We're seeing a decreasing trend in perennial ice coverage," he said. "Our study suggests that, on average, the area of seasonal ice that survives the summer may no longer be large enough to sustain a stable perennial ice cover, especially in the face of accelerating climate warming and Arctic sea ice thinning."

Data from the 2005-06 season have not yet been analyzed.

The study appeared March 2 in *Geophysical Research Letters*.

For more information about QuikSCAT, visit: *winds.jpl.nasa.gov/index.cfm*. ■

In this detailed, photo-like image of Arctic sea ice, captured on June 16, 2001, by NASA's Landsat-7 satellite, sea ice is spread across the nearly black backdrop of the Arctic Ocean in a broken mosaic. Large blocks of ice swirl against finely crushed ice that looks almost like foam. The dark ocean surfaces absorb incoming sunlight, while sea ice reflects it. A cooling climate increases snow and ice, which increases solar reflection, leading to more cooling. Warming climates cause snow and ice to melt, which increases solar absorption, leading to more warming. **Credit**: NASA image by Robert Simmon, based on Landsat-7 data from the Global Land Cover Facility.



CloudSat and CALIPSO: A Long Journey to Launch …But What a Year It's Been!!

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Introduction

The CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellites celebrated their first anniversary in orbit recently, but the history leading up to these missions actually dates back more than a decade. Prior to 1996, two separate teams, one at NASA Langley Research Center (LaRC) and one at NASA Jet Propulsion Laboratory (JPL) came up with a concept for a mission that would study aerosols and clouds. Their vision was to combine existing technologies, like those from the Clouds and the Earth's Radiant Energy System (CERES), and the Lidar In-space Technology Experiment (LITE), with a space-based radar to create one large Earth observing satellite. However, in 1996, the opportunity to propose under the Earth System Science Pathfinder (ESSP) program arose. ESSP called for relatively low-to-moderate cost, small to medium-sized missions capable of being built, tested, and launched in a short time interval, and so the idea of a large combined spacecraft was abandoned. Instead, NASA Langley and JPL each proposed separate missions. The teams quickly realized however that coordination of the spacecrafts could still be possible and continued to work closely with each other.

In 1998, NASA decided on two separate missions—one applying radar technology, and one applying lidar technology from LITE—and CloudSat and CALIPSO were chosen as part of the ESSP program. It was later realized that a combined data set could be achieved by flying the satellites in formation. The two satellites would share the same launch vehicle and then fly in tandem as part of the Afternoon or "A-Train" Constellation.

Why study aerosols? *Clean air is vital to life on Earth. An average adult breathes more than 3000 gallons of air every day. In some places, the air we breathe is polluted by small particles in the atmosphere known as aerosols. Many natural processes—e.g., forest fires and wind-blown desert dust—produce large amounts of aerosols, but roughly half of the total aerosols worldwide results from human activities—e.g, driving cars and trucks, burning coal and oil, and manufacturing chemicals. In high enough concentrations, pollution aerosols can threaten human health. Aerosols can also impact our environment and even contribute to changes in Earth's climate. Aerosols reflect sunlight back to space, cooling the Earth's surface, and some types of aerosols also absorb sunlight—heating the atmosphere. Because cloud particles form on aerosols, changes in aerosols can change clouds and even precipitation. In order to improve daily forecasts of air quality and long-term forecasts of climate change, scientists need better information (on a global scale from satellites) on where aerosols are produced and where they travel.*

After a series of launch delays—the last caused ironically enough by low clouds over the launch site—the joint CloudSat-CALIPSO launch finally happened. More than a decade of planning and preparation finally came to fruition as a Boeing Delta II rocket carrying both satellites roared into orbit on April 28, 2006, and CloudSat and CALIPSO took their respective places in the "A-Train" of polar-orbiting sun-synchronous missions dedicated to the study of Earth's climate. CloudSat and CALIPSO joined NASA's EOS Aqua and Aura satellites and France's Polarization & Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL) mission—they may later be joined by NASA's Orbiting Carbon Observatory (OCO) and Glory missions.

Together, CloudSat and CALIPSO seek to overcome shortcomings in the representation of clouds and aerosols in climate and weather forecast models and provide the first global survey of large-scale and seasonal variations in the vertical structure and frequency of occurrence of clouds and aerosols. Such measurements represent a significant advance over our previous observing capabilities and the new information should improve scientists' understanding of the role clouds and aerosols play in regulating Earth's climate.

CloudSat's only payload instrument is a 94 GHz cloud-profiling radar (CPR). The CPR is unique among Earth-observing sensors because of its ability to provide key vertically-resolved measurements of the properties of clouds, yielding insights on the significant influences of clouds on our planet's weather, water cycle and energy balance.

CALIPSO seeks to help scientists answer significant questions and provide new information concerning the effects of aerosols—airborne particles—and thin clouds on changes in Earth's climate. This new information will enable more accurate climate model predictions that will help policy makers make more informed decisions about how to respond to global change. CALIPSO combines an active instrument called the Cloud Aerosol Lidar with Orthogonal Projection (CALIOP) with an Imaging Infrared Radiometer (IIR) and Wide Field Camera (WFC), which are passive infrared and visible imagers, respectively. These three instruments can probe the vertical structure and properties of thin clouds and aerosols over the entire globe and complement measurements by CloudSat.

The A-train operates as a virtual platform with cooperation manifest between the missions and integration of data from the various satellites' instruments a vital goal. CloudSat flies in tight formation with CALIPSO, being positioned just 15-seconds along-track ahead of CALIPSO. Both CloudSat and CALIPSO fly in formation with Aqua, which leads the A-Train. CloudSat's average distance behind Aqua is approximately 60 seconds. For the purposes of coordinated, overlapped radar/lidar observations, CloudSat maintains a groundtrack matched to CALIPSO's to within ±1 km. This results in the CloudSat and CALIPSO footprints overlapping more than 90% of the time.

Why study clouds? *There is a lot of water on Earth, but relatively little is usable to humans. Of the small amount of freshwater on our planet, two-thirds of it is locked away in ice caps at the poles. The remaining freshwater resides in lakes, rivers, and in underground reservoirs. Clouds play an important role in the cycling of water over the planet. They effectively wring out some of the invisible water vapor contained in the atmosphere and convert it to liquid and solid water that falls back to Earth, replenishing our reservoirs of freshwater. There is still a great deal we do not know about clouds and the water cycle, such as how much of the water in clouds falls as rain or snow, and we cannot predict how clouds—and thus our reservoirs of freshwater—might change as our climate changes. Clouds regulate how much solar radiation reaches Earth, the amount of heat Earth returns to space, and the water cycle of the planet. Scientists need better global information on clouds so they can begin to answer some of these difficult questions.*

Now, one year after the launch, *The Earth Observer* staff caught up with representatives of each mission and asked for a status report and highlights of the first year in orbit.

CloudSat

Thanks to CloudSat's successful ground-breaking first year, many intriguing questions about the processes that occur in clouds have been answered—and the research is just beginning. The CloudSat radar was first activated on May 15, 2006 [1] and was switched to full operational mode on June 2, 2006 . In the first eight months of operations, CloudSat has generated over 130 million vertical profiles of the troposphere. The CloudSat project has accelerated the early use of its data, promoting extensive science community involvement. The interest in these data from the science community outside of CloudSat has been enormous, with over 114,000 files (1.8 terabytes) served as of February 1, to users in 15 countries. Since launch, more than 14 significant papers are in preparation, have been submitted or have been published.

Early scientific results are exciting. CloudSat always anticipated that new discoveries would quickly emerge from analysis of matched data sets from multiple platforms. The results have met and exceeded expectations. CloudSat has successfully: (1) demonstrated the technique of precision formation-flying with its A-Train parners; (2) incorporated Moderate Resolution Imaging Spectroradiometer (MODIS) data in CloudSat standard data products and begun the merging of CALIPSO lidar data with CloudSat radar data; (3) developed co-registered MODIS and cloud radar datasets for community use; and (4) initiated scientific studies involving observations from multiple A-Train platforms.

CloudSat has provided the first highly accurate global direct measurements of cloud-base height, at a resolution of 500 m, which is needed to deduce the longwave flux to the surface with errors less than 5-10 W/m^2. Before CloudSat, it was only possible to infer cloud-base height with empirical methods usually tied to cloud-top heights. Now, for the first time, researchers can observe the properties of clouds and the precipitation that falls from those clouds at the same time (both have been studied separately in the past). CloudSat scientists

[1]See **July–August 2006** issue of *The Earth Observer* [Volume 18, Issue 4, pp. 5-7] to view "first-light" images from CloudSat and CALIPSO.

have begun estimating the precipitation efficiency of cloud systems, as well as constraining and improving the ice and water content of the atmosphere in weather and climate models. Additional results include determining the effect of clouds on the atmospheric energy balance, studying the timeline of the autoconversion process in warm-rain clouds and estimating the intensity of hurricanes.

"It perhaps is appropriate that CloudSat's historic first view of clouds was of a weather front connected to a mid-latitude cyclone. It was the study of these weather phenomena that heralded the beginning of modern meteorology almost a hundred years ago. Over this past year, CloudSat has shown us stunning views of all types of weather systems, and is revealing all sorts of new insights on the weather of our planet. One example is the insight now being gathered on raining clouds—it appears that clouds precipitate much more frequently than we had previously expected. This is absolutely essential context for understanding climate change."

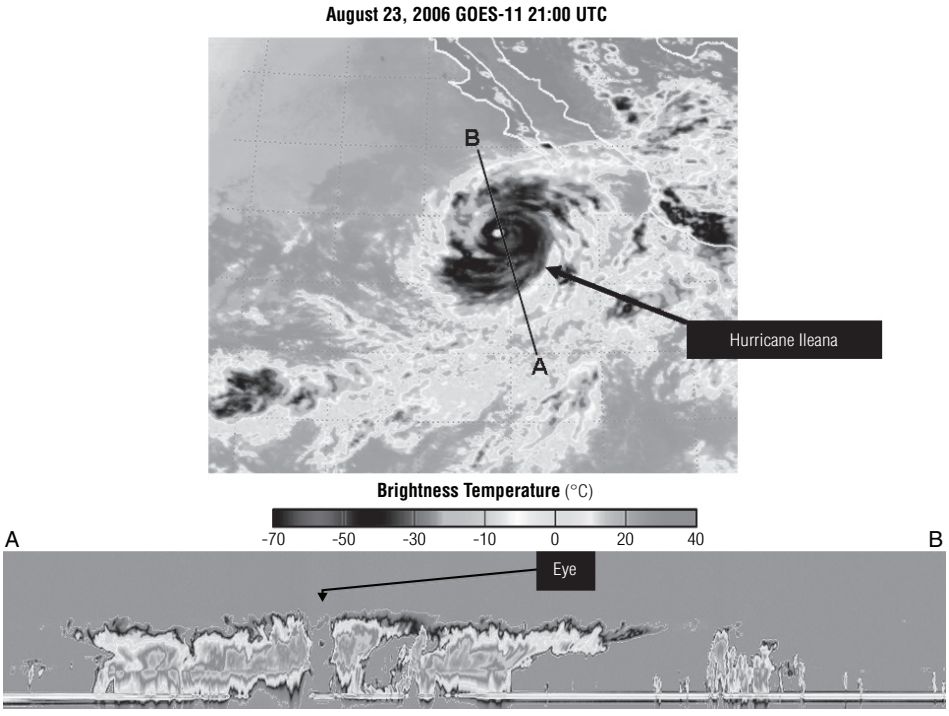
—Graeme Stephens, CloudSat Principal Investigator

In addition to the obvious intrinsic value of comparing *like* products from different sensors, unanticipated new discoveries are emerging from analysis of the various matched data sets being constructed by CloudSat. A completely novel approach to observe the rain conversion process has been developed. The method evolves out of the unique synergy between CloudSat CPR data and data from the MODIS on Aqua. Up to now, models have predicted slower times between cloud formation and precipitation than is observed in nature. A comparison of the rate of rain-water production derived from matched CPR and MODIS observations as a function of cloud water identifies a range of time scales more rapid than theory suggests, but consistent with observational experience. This is a significant result that will provide an entirely new constraint on the tuning of parameterizations of warm rain in global models. The combination of CloudSat data with MODIS data also provides a fundamentally new way of estimating the intensity of tropical cyclones using remote sensing methods.

The CloudSat mission has requested authorization from NASA to extend its successful mission. Extending the CloudSat mission beyond its current 22-month operational lifetime provides the opportunity to study significant hydrological processes in the context of weather and climate variability, including such critical

CloudSat literally adds a whole new dimension to our ability to observe hurricanes and other storms from space. These two images of Hurricane Ileana were taken on August 23, 2006. The top image shows a "conventional" two-dimensional view of the storm from NOAA's Geostationary Operational Environmental Satellite (GOES)-11. The highest cloud tops have the lowest brightness temperature.

The bottom image adds the third dimension by showing a vertical cross-section of *Ileana* as Cloudsat's Cloud Profiling Radar (CPR) passes over the storm moving from point A to point B as shown on the GOES image. **Credit:** CIRA CloudSat Data Processing Center.



modes of the Earth's climate system as the Madden-Julian Oscillation (MJO) and El Niño. Additionally, an extended mission will greatly increase the opportunities to study clouds as a function of environmental properties such as changing sea-surface temperatures. Two new classes of products are proposed as an enhanced science effort: precipitation products for snow and rainfall, and a cloud microphysical properties product.

In addition to the early success of the scientific goals of the mission, CloudSat has an equally important goal of reaching out to young people to interest them in science and technology, perhaps even as career choices. The centerpiece of the CloudSat education and outreach program is a network of schools around the world—a subset of NASA GLOBE schools—where students are engaged in making cloud and precipitation observations during CloudSat overpasses and conducting research with radar data. These observations are shared on the CloudSat website with other GLOBE schools and the CloudSat Science Team. The CloudSat Education Network (CEN) consists of approximately 100 schools and over 3000 students from 12 countries (Canada, Thailand, India, New Zealand, Germany, Australia, Estonia, Croatia, United States, Cameroon, France, and the Dominican Republic). In the U.S., nine states and Puerto Rico currently have CEN schools. CloudSat scientists, including the Principal Investigator and the Project Manager, interact continually with students through site visits, attendance at workshops, e-mail, online forums, and contribution of educational materials. Just since the April 2006 launch, school site visits have brought CloudSat scientists and educators into face-to-face contact with approximately 1000 students.

"Student observations of cloud types during CloudSat overpasses is a real opportunity for students to be involved in NASA research, while they learn about meteorology and climate issues."

—Deborah Vane, CloudSat Project Manager

CloudSat Principal Investigator Graeme Stephens and Project Manager Deborah Vane (back row) visit Woolaning School, a CloudSat school in northern Australia.

CALIPSO

Minutes after the successful launch, the CALIPSO Mission Operations Team started payload checkout. This period lasted for the entire month of May, and then, on June 7, CALIPSO had its "first light." CALIPSO's first lidar images offered an exciting and unique vertical view of layers of clouds and aerosols. One mission goal of CALIPSO is to better understand how aerosols are transported over the globe, and the "first light" data illustrates CALIPSO's ability to detect and track volcanic plumes. Using comparisons with the Ozone Monitoring Instrument (OMI) on NASA's Aura spacecraft, the CALIPSO Science Team was able to identify a volcanic plume over Indonesia that originated in the Caribbean, where a major lava dome collapse took place at the Soufriere Hills Volcano on the island of Montserrat. Researchers said that because of the altitude and the correlation with the location of the plume, the very thin layer of clouds in the CALIPSO data appears to be the aerosol component of the plume from Soufriere. The layer appears to be non-depolarizing, so it may be primarily composed of sulfuric acid droplets, rather than ash particles. CALIPSO's ability to observe the location, altitude, optical properties and movement of aerosols around the globe improves our ability to assess and forecast episodes of poor air quality.

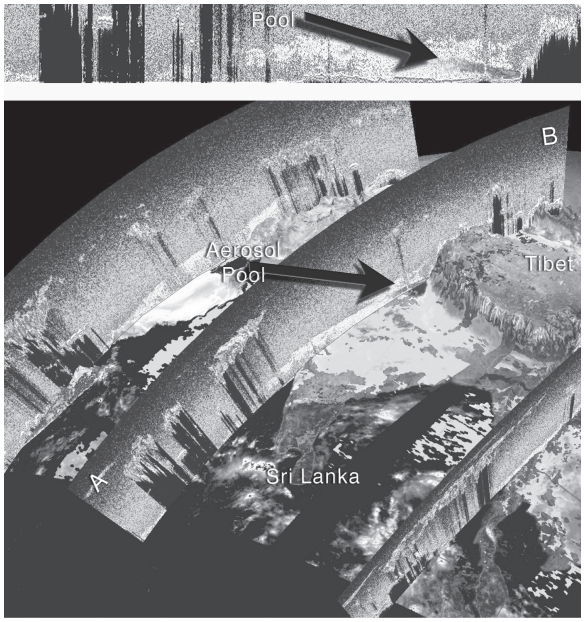
"From the day CALIPSO launched, we haven't stopped running at full speed,"

—Chip Trepte, CALIPSO Project Scientist

A number of papers have been published, and many more are in the works describing the exciting scientific features already seen in the CALIPSO data. For example, researchers are using CALIPSO data to:

- track Saharan dust;
- view the distribution of high altitude clouds;
- identify and study smoke plumes from biomass burning;
- track injection of volcanic aerosols into the atmosphere (similar to the first light images); and
- view polar stratospheric clouds in three dimensions.

Additionally, the CALIPSO Science Team is working to combine CALIPSO data with data from Aqua MODIS and the Atmospheric Infrared Spectrometer (AIRS)—also on Aqua—to improve aerosol and cloud products from these instruments. For example, CALIPSO can "see" thin clouds that are invisible to MODIS, helping to improve the MODIS aerosol products. They are also working to combine CALIPSO data with data from the CERES on Aqua to better understand radiative flux.



The northern region of India near New Delhi frequently suffers from very poor air quality. The towering Himalayan mountains nearby act as a wall and trap polluted air causing the tiny atmospheric particles called aerosols to "pile up" or "pool" in this area.

The top image shows aerosol and cloud observations (measurements of the total attenuated backscatter at 532 nm from CALIOP) as CALIPSO passed over the region on October 25, 2006, from Point A to Point B. The arrow points to the area of strongest interest for the CALIPSO Science Team—*an aerosol pool*. The Himalayas show up as a jagged hump just to the right of the arrowhead.

When CALIPSO observations are combined with data from MODIS on Aqua and Terra, scientists can literally add a new dimension to their ability to observe aerosols and thin clouds. They can get a three-dimensional cross section of the atmosphere from the surface to 20 km wherever CALIPSO passes over. The bottom image shows lidar data from three different CALIPSO overpasses (moving from Point A to Point B across the scene) overlayed on MODIS aerosol data from both Terra and Aqua. The bottom arrow points to the CALIPSO-observed aerosol plume and corresponds well with the aerosols observed by MODIS. Adding CALIPSO's vertical profiling capabilities has allowed scientists to confirm that the aerosols that MODIS observes over this region occur low in the atmosphere, very close to the ground level.

In December 2006, just before the Fall American Geophysical Union Meeting, the first CALIPSO data were released to the public. This data release consisted of data beginning in mid-June 2006 and included Level 1 radiances from each of CALIPSO's three instruments (lidar, wide field camera, and imaging infrared radiometer). This release also includes the lidar Level 2 vertical feature mask, and cloud and aerosol layer products. The CALIPSO data are available through the Atmospheric Sciences Data Center (ASDC) at NASA Langley Research Center and can be accessed at: *eosweb.larc.nasa.gov/PRODOCS/calipso/table_calipso.html.* As of mid-April 500 million profiles have been collected.

"A lot of people worked really hard planning and developing the CALIPSO mission and all their hard work is paying huge dividends now. CALIPSO on-orbit operations have been essentially flawless and CALIPSO science data are simply stunning."

—Mike Cisewski, CALIPSO Operations Manager

All-in-all, the CALIPSO mission team is very pleased with their first year on orbit and is looking forward to continued operations and data analysis.

CloudSat/CALIPSO Validation Activities

A major validation experiment for both CALIPSO and CloudSat, called the CALIPSO and CloudSat Validation Experiment (CCVEx), a major validation experiment for both CALIPSO and CloudSat, was conducted from Robins AFB at Warner Robins, GA from July 26 to August 14, 2006. The experiment was designed to acquire coincident cloud and aerosol measurements to verify lidar and radar calibration, stability, and sensitivity, and the accuracy of CALIPSO and CloudSat data products. Three aircraft were deployed to fly under the satellite overpasses: the Dryden ER-2 equipped with the Cloud Physics Lidar, Cloud Radar System, and MODIS Airborne Simulator (MAS); the LaRC King Air equipped with the High Spectral Resolution Lidar (HSRL) instrument; and the Weather Modifications Inc. LearJet equipped to make *in situ* particle instruments. Researchers conducted eight daytime and four nighttime deployments and successfully achieved all pre-mission flight objectives. The results of CCVEX, as well as data taken in other validation activities, were examined by the CALIPSO Science Team at their meeting held October 3–5, 2006, and by the CloudSat Science Team at their meeting held October 16–20, 2006.

A Canadian-sponsored four-month validation effort called the Canadian CloudSat/CALIPSO Validation Project ran from November 2006 to February 2007, and focused on the validation of cold cloud and precipitation—http://*c3vp.org/*. The Meteorological Service of Canada (MSC), Environment Canada, performed extensive validation of the satellite products in the context of the Canadian climate.

Additional validation opportunities have included measurements made during the NASA African Monsoon Multidisciplinary Analyses (NAMMA) campaign off of the coast of Africa—*namma.msfc.nasa.gov/amma.html*—and underflights that took place during the Cirrus and Anvils: European Satellite and Airborne Radiation (CAESAR) Project led by the United Kingdom Meteorological Office in January 2007, and will also include participation in the upcoming NASA field

program called Tropical Composition, Cloud, and Climate Coupling (TC4) in Costa Rica this summer—*www.espo.nasa.gov/tc4/*.

In addition to all of these joint efforts, each mission participates in separate validation activities. Researchers have used the Langley airborne HSRL flown on the King Air to make measurements in the Hampton Roads, VA area coincident with CALIPSO's lidar. Furthermore, the CALIPSO team has collaborated with the European Aerosol Research Lidar Network (EARLINET), an international lidar network for ground-based lidar coincident measurements. As for CloudSat, flights of the University of Wyoming's Cloud Radar are planned for later this year to coincide with CPR overpasses. ■

Kudos

Following are recipients of American Geophysical Union (AGU) awards for 2007 that are affiliated with NASA's Earth Observing System (EOS).

Edward A. Flinn III Award
"The Edward A. Flinn III Award recognizes individuals who personify the Union's motto 'unselfish cooperation in research' through their facilitating, coordinating, and implementing activities that have strengthened the infrastructure on which our research depends. This award is for the unsung heroes who provide the ideas, motivation, and labors of love that build and maintain the structure without which our science could not flourish."

This year's recipient was **Diane E. Wickland,** NASA Headquarters—"in recognition of her lifelong contributions to the international geophysical science community."

AGU Fellows
"This designation recognizes members and others who have made outstanding contributions to the advancement of the geophysical sciences, to the service of the community, and to the public's understanding. It is conferred upon not more than 0.1% of all AGU members in any given year. The new Fellows are chosen by a Committee of Fellows."

Dennis D. Baldocchi, University of California, Berkeley, CA
Timothy S. Bates, NOAA Pacific Marine Environmental Laboratory, Seattle, WA
Anne R. Douglass, NASA Goddard Space Flight Center, Greenbelt, MD
John C. Gille, National Center for Atmospheric Research, Boulder, CO.
Umran Inan, Stanford University, Palo Alto, CA
William K. M. Lau, NASA Goddard Space Flight Center, Greenbelt, MD
William J. Parton, Colorado State University, Fort Collins, CO
John C. Schaake, NOAA National Weather Service, Silver Spring, MD
Kevin E. Trenberth, National Center for Atmospheric Research, Boulder, CO
Douglas R. Worsnop, Aerodyne Research, Inc., Billerica, MA

The *Earth Observer* staff and the entire scientific community would like to congratulate these colleagues on this outstanding achievement.

Ocean Surface Topography Science Team Meeting

Lee-Lueng Fu, Jason-1 Project Scientist, NASA Jet Propulsion Laboratory, Lee-Lueng.Fu@jpl.nasa.gov

Introduction

The 2007 Ocean Surface Topography Science Team (OSTST) Meeting was held in Hobart, Australia, on March 12-15. Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) hosted the meeting with support from the Australian Bureau of Meteorology Research Centre (BMRC) and the Royal Australian Navy (RAN). The Governor of Tasmania**, His Excellency the Honorable William Cox**, officially opened the meeting and welcomed the participants to Hobart. **Neville Smith** [BMRC—*Chief Scientist*] also welcomed the group and noted that this was the first OSTST meeting ever held in the southern hemisphere. **Commander Andrew McCrindell** [RAN] delivered a keynote presentation on applications of satellite altimetry to Australian naval operations.

In his opening remarks, **Lee-Lueng Fu** [NASA/Jet Propulsion Laboratory (JPL)—*Jason-1 Project Scientist*] recognized the strong participation of Australian oceanographers in precision altimetry over the past two decades and expressed appreciation for the opportunity to meet in Hobart and interact with local participants. He also acknowledged the excellent assistance of **David Griffin** [CSIRO—*Research Scientist*] in the planning of the meeting and logistics support.

Program and Mission Status

Eric Lindstrom [NASA Headquarters—*Physical Oceanography Program Scientist*] and **Eric Thouvenot** [Centre National d'Etudes Spatiales (CNES)] spoke on the status of altimetry and oceanography programs at NASA and CNES. Lindstrom discussed the overall NASA program and the role of Earth sciences including the next two oceanography missions: Ocean Surface Topography Mission (OSTM)/Jason-2 to be launched in 2008 and Aquarius scheduled for 2009. He also addressed the plan to renew the OSTST in 2008 as announced in NASA's Research Opportunities in Space and Earth Sciences (ROSES) Program.

Thouvenot reported on the CNES altimetry program focusing on OSTM/Jason-2 and the *AltiKa* altimeter (Ka band altimeter). *AltiKa* is to be launched on the Satellite with ARgos and *ALtika* (SARAL) Mission, a joint mission with the Indian Space Research Office (ISRO) in 2009-2010. CNES is also committed to contribute a Proteus spacecraft and project team support to Jason-3, planned as a joint mission involving CNES, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and NOAA. The contemplated launch date is 2012. CNES is also planning to participate in a future wide-swath altimetry mission.

Sophie Coutin-Faye [CNES] presented the CNES status of Jason-1, which has delivered 95% of science data since the last OSTST meeting. The payload status is very good. CNES and NASA signed a five-year mission extension agreement in December 2006.

Glenn Shirtliffe [JPL—*Jason-1 Project Manager*] presented the status of the NASA portion of Jason-1. Since the 2006 OSTST meeting in Venice, Italy, no science or engineering data have been lost due to NASA ground-system anomalies or command errors. Excluding the two-week safe hold event in October-November 2006, the total data recovery rate exceeds 99.97% of all available science data. Geophysical data records (GDR)-B data reprocessing is going well and is near completion. Both Turbo Rogue Space Receiver global positioning system (GPS) receivers have failed to function properly, and the quality of GPS-based orbit determination has been deteriorating since mid 2006. However, Jason-1 precision orbit determination continues meeting science requirements based on the Determination d'Orbite et Radiopositionement Integre par Satellite (DORIS) and Laser Retroreflector Array (LRA) instruments.

Nicolas Picot [CNES] reported on the status of Service d'Altimétrie et de Localisation Précise (SALP), a multi-mission altimetry and orbit data processing center, and the GDR reprocessing. SALP archives data from TOPEX/Poseidon (T/P), and processes data from Jason-1, Envisat, and Satellites Pour l'Observation de la Terre (SPOT). Preparations for Jason-2 and *AltiKa* are underway. For Jason-1 the focus is on GDR-B reprocessing that should be completed in a few weeks. GDR-C reprocessing is expected to start in early 2008 for cross-calibration of OSTM/Jason-2.

Gerard Zaouche [CNES] reported on the status of OSTM/Jason-2 and described how mission responsibilities are shared by the four partners: CNES, EUMETSAT, NOAA, and NASA. Near-real-time operational geophysical data records (OGDR*)* products will have a 10-cm orbit with re-tracked sea surface height and improved resolution near coasts. Special data products for coastal and inland water applications will be available. OSTM/Jason-2 will be launched into an orbit one minute ahead of Jason-1 along the same ground tracks for cross-calibration. Payload integration started in December 2006. Satellite integration and testing will be conducted from June 2007 to January 2008. End-to-end ground system testing is scheduled for completion before May 2008. Launch is scheduled for mid-June 2008.

Other Ongoing and Future Missions Status

Jocelyne Noubel [CNES] provided more details on the joint CNES/ISRO *AltiKa*/SARAL mission, a gap filler mission between Envisat and Sentinel-3 that will carry a Ka band (35.75 GHz) radar altimeter, a two-frequency (23.8 and 37 GHz) microwave radiometer, a DORIS receiver and a laser retroreflector. The launch date is in 2009-2010.

Lee-Lueng Fu [JPL] presented the status of the development of a wide-swath altimetry mission. The recently released National Research Council's Decadal Survey recommended combining the concepts of the Water And Terrestrial Elevation Recovery (WaTER) and the Hydrosphere Mapper missions into a single mission to address the objectives of both the land hydrology and oceanography communities. Since last year's OSTST meeting, the two communities held two joint meetings, a workshop in October and an American Geophysical Union session in December, leading to a consolidated mission concept—called the Surface Water and Ocean Topography (SWOT) mission. A key mission design issue is the choice of orbit, and the OSTST discussed the impact of a sun-synchronous orbit on the oceanography objectives. (The Tides and High Frequency Aliases splinter session discussed this issue in greater detail—see below.) The conclusion was that a sun-synchronous orbit was not acceptable for meeting oceanographic objectives.

Jerome Benveniste [ESA] gave a presentation on the status of the European Space Agency (ESA) missions. He reported that:

- ESA's Living Planet Programme has a series of approved missions of direct interest to OSTST. See: *www.esa.int/livingplanet*.
- The Earth Explorer missions address key questions about the Earth system.
- The Gravity Field and Steady-State Ocean Circulation Explorer (GOCE), the Soil Moisture and Ocean Salinity (SMOS) mission and CryoSat-2 are all scheduled for launch within the next 2 years.
- The six short-listed "7th Explorer" are the subject of feasibility studies.
- Sentinel's development is ongoing. Sentinel 3 will focus on medium-resolution ocean monitoring with wide-swath ocean color and surface temperature sensors and a synthetic aperture radar altimeter.
- Studies and algorithm development in support of missions are ongoing and planned this year.
- Envisat Radar Altimeter (RA)-2 Ultra-Stable Oscillator (USO) is in good health, monitored and drift corrected.

Stan Wilson [NOAA—*Senior Scientist, NOAA Satellite & Information Services*] and **Francois Parisot** [EUMETSAT] reported on the status of Jason-3:

- Jason-3 has been clearly identified as priority one in Europe for satisfying the needs of the Marine Core Services within the Global Monitoring for Environment and Security (GMES) initiative.
- The EUMETSAT/NOAA approach has been endorsed at high level. Letters between EUMETSAT, NOAA, and CNES confirm the commitment of these agencies on Jason-3.
- EUMETSAT and NOAA have established a focus group and application and implementation groups with participation of CNES, NASA, and others.
- To ensure continuity with Jason-2 and minimize cost and risk, the proposed Jason-3 mission is to be based on a maximum of recurrence with Jason-2, with the choice of orbit still open.
- The question of an appropriate orbit for Jason-3 was raised to the OSTST.

Science Plenary Sessions

Before the start of the plenary science session, **Lee-Lueng Fu** presented a brief tribute to Roman Glazman, an OSTST member who passed away last April.

Twelve invited talks in the plenary session reviewed the progress in OSTST science investigations to date.

- **Dudley Chelton** [Oregon State University] *Global observations of westward energy propagation: Rossby waves or nonlinear eddies?*
- **Bo Qiu** [University of Hawaii] *Eddy-mean flow interaction: insights from satellite altimetry measurements*
- **John Church** [CSIRO] *Understanding sea-level rise*
- **Dean Roemmich** [Scripps Institution of Oceanography, University of California San Diego (USCD] *Observing decadal variability in the oceans*
- **Tony Busalacchi** [University of Maryland] *Seasonal to interannual variability of global sea level: recent progress in monitoring and prediction*
- **Rui Ponte** [Atmospheric and Environmental Research, Inc.] *Large-scale subseasonal sea level variability over the global ocean*
- **Peter Niiler** [Scripps Institution of Oceanography, UCSD] *Combining ocean velocity observations and altimeter data for OGCM verification*
- **William Emery** [University of Colorado] *Ocean surface topography applications to circulation mapping in the coastal ocean*
- **Gary Egbert** [Oregon State University] *Internal tides, tides in shallow seas and altimetry*
- **Anny Cazenave** [Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)-CNES] *Monitoring terrestrial surfaces waters by satellite*
- **Tony Lee** [JPL] *Ocean state estimation for studies of climate variability*

- **Eric Dombrowski** [Mercator Océan] *Operational oceanography*

Poster Session
Posters were grouped into the following categories:

- Science results (modeling/data assimilation, mean dynamic topography, tropical ocean, coastal ocean, sea level, ocean circulation/air-sea interaction, ocean eddies, land/ice/hydrology);
- Local and global calibration/validation;
- Precision orbit determination (POD) and geoid;
- Multi-satellite/operational applications;
- Tides and high-frequency aliases;
- Sea-state bias and re-tracking analysis; and
- Outreach.

Splinter Sessions
The proposed theme for the splinter sessions—in particular for the calibration/validation, POD/geoid, tides/high frequency aliasing, and sea-state bias/retracking groups—is the error budget of altimetry products. **Rui Ponte**, who proposed the theme, made a brief introduction to the subject before the start of the splinter sessions. He stressed several areas he felt the splinter groups should consider during their discussions.

- Basic errors in Jason-1 and T/P data resulting from such sources as radar noise, orbit error, environmental corrections (e.g., wet and dry troposphere, ionosphere, sea-state bias), and models (e.g., tides, inverted barometer (IB), high frequency correction).
- Basic errors in data from other missions, from combined data products, etc.
- Special topics such as methodologies to estimate errors, characterization of spatial and temporal behaviors, errors in the time-mean topography and mean sea-level trends, and correlation structures.

Calibration/Validation
General conclusions of the splinter session are that:

- The Jason-1 GDR sea surface height (SSH) remains biased (high);
- there is no significant drift in Jason-1 bias (GDR-B);
- there is no detectable drift in Jason Microwave Radiometer (JMR) path delay;
- the sea surface height (SSH) bias in T/P altimetric measurement has decreased; and
- there is no significant drift in altimeter-B in T/P altimeter measurement systems.

POD and Geoid
Conclusions for this splinter group are subdivided into POD and Geoid.

General conclusions from the **POD** discussion are that:

- The Jason-1 GDR-B orbits are centimeter level orbits;
- new standards should be ready by the end of the year to support the GDR-C reprocessing—and Jason-2;
- at the current level of precision, geocenter motion should probably be taken into account, but there is a lack of consensus on which model to use; and
- margins of improvement appear limited for the future.

General conclusions from the **Geoid** discussion are that:

- The next generation of geoid models will continue to increase the resolution of gravity as seen from space;
- the emphasis of combination solutions tends to minimize 'striations' and other data artifacts;
- some smoothing of the implied ocean topography will always be required, if only due to truncation, but we hope to reduce the smoothing radius from the current ~400 kilometers; and
- it is important to continue to refine methods to extract the best estimates of the mean dynamic topography considering the accuracy and limitations of the Gravity Recovery and Climate Experiment (GRACE) geoids.

Sea-state Bias (SSB) and Retracking
General conclusions from this splinter group are that:

- The algorithm MLE4 for retracking is ready;
- SSB processing is ready. A new version will be computed as soon as other information—e.g. the final CNES orbit—becomes available; and
- T/P re-tracking should be completed within about one year and will require extension of the present OSTST task into fiscal year 2008.

Tides and High-frequency Aliasing
The following topics were highlighted in this splinter group's discussion.

- The group continued the discussion of sun-synchronous orbits for SWOT begun in the earlier plenary session and concluded that there were strong arguments against sun-synchronous orbit—e.g., not useful for tides, corruption of climate signals by diurnal errors, corruption of mean absolute dynamic topography, corruption of the seasonal cycle—and far fewer strong arguments for sun-synchronous orbit other than engineering and cost issues.
- The group discussed a slight upgrade in FES2004 to correct some problems with S1 and K2 tides.
- The group also had discussions about:
  - A new validation data set from Richard Ray [NASA Goddard Space Flight Center] that

requires consideration of the contribution of shallow water tidal impacts, especially from Australia;
- improvements in high frequency or dynamic atmospheric correction from a much higher resolution *MOG2D* version;
- the status of current Aviso products wherein the S1 tide solution is not optimal and some technical issues related to the filtering of the pressure forcing need to be addressed;
- the use of baroclinic models and data assimilation methods may provide further improvements for dynamic atmospheric correction; and
- surface atmospheric pressure errors provided from comparisons of surface atmospheric pressure analyses and data, important for uncertainty in dry tropospheric, IB and dynamic atmospheric corrections.

Multi-satellite and Operational Applications

Science team members covered a wide range of topics in the session including: data assimilation, waves, fisheries applications, data provision, coastal and regional studies, and observing systems. The splinter group concluded that:

- At least two satellites are required to be able to address mesoscale variability;
- assimilation of different data types increases redundancy in the Global Ocean Observing System;
- altimetry is considered the foundation of operational applications; and
- the extension of altimetry towards the coast is an essential requirement for the future.

Outreach

This session highlighted activities targeting the three main categories of outreach audiences: data users, education, and general public through the media. Participants reported on the outreach highlights of the previous year and current activities. Discussion continued with participant talks on the ESA/CNES Basic Radar Altimetry Toolbox (BRAT) and Radar Altimetry Tutorial (RAT), teaching undergraduate oceanography, an update on operational applications, ocean literacy support efforts, news and public interest in ocean altimetry, and a discussion of using visual aids to promote public understanding of climate change, sea level rise and polar science. An "altimetry product showcase" of outreach activities from nine members of the science team was presented at the end. Current OSTST outreach is being linked to a national, multi-organizational ocean literacy effort in the U.S.

Robert Stewart [Texas A&M] presented information about the web-based oceanography textbook he is writing, which is organized around real-life problems that emphasize the connections among Earth systems and the contributions of NASA to understanding oceans. Outreach team members encouraged OSTST members to submit examples of their efforts to inform the public about ocean science research and applications.

The splinter group also discussed future plans including:

- Jason-2/OSTM education and public outreach and applications outreach;
- altimetry applications, including multi-sensor/multi-satellite applications
- coverage of science team research and other applications on the web;
- refurbishment of the Aviso web site with increased news frequency beginning before Jason-2;
- expanding the *Argonautica* program near the Jason-2 launch; and
- participation in the International Polar Year activities.

Conclusions

Science

Lee-Lueng Fu briefly summarized the outstanding science progress reviewed in the meeting. The data record from T/P, Jason-1 and the European Remote Sensing satellite (ERS) has provided unprecedented views of ocean variability on decadal scales, revealing interesting large-scale patterns of ocean circulation and air-sea interactions in all ocean basins. Such decadal variability was used to simulate the variability of global sea level change in the past 100+ years, revealing interesting decadal variability in global mean sea level rise and acceleration.

New maps of global ocean general circulation have been reconstructed from the combination of surface drifter and satellite altimetry observations, revealing remarkable zonally-oriented narrow currents. New findings on ocean eddies and their propagation raise questions on the roles of Rossby waves versus eddies in the ocean's response to atmospheric forcing. The study of the interaction between eddies and large-scale circulation and its variability has been significantly advanced by merged T/P, ERS, Jason-1 and Geosat Follow-On (GFO) data.

Challenges still remain in the study of coastal tides and circulation, but significant progress has been made

and future promise identified. Modelling and data assimilation are responsible for remarkable progress in the understanding of climate variability from seasonal, to interannual, to decadal time scales, as well as in the operational applications of altimetry observations. A growing field of study is applications of altimetry to the study of inland waters, which seems to offer great potential for breakthroughs using future wide-swath observations that could also have practical benefits for society.

Altimetry Error Budget

Tremendous progress has been made in reducing errors in altimetry measurements. For example, the *two-centimeter challenge* posed by Michel Lefebvre (CNES, retired) led by the United Kingdom Meteorological Office before the launch of T/P has been met by the POD effort. However, remaining instrument errors—e.g., sea-state bias, T/P-Jason-1 bias, etc.—still pose challenges for the future. The details of the error budget of the state-of-the-art altimetry products are beyond the scope of the meeting. Fu proposed that all the splinter group leaders consider working together on a review paper summarizing the current state of understanding. Such an effort is timely considering the growing importance of altimetry in the many wide-ranging applications discussed in the meeting.

Future Missions and Recommendations

One of the teams biggest concerns is that the precision altimetry data record established over the past two decades continue beyond OSTM/Jason-2. Although missions like AltiKa and Sentinel-3 have been approved and are proceeding, these missions are not designed for large-scale climate studies. Jason-3 and SWOT are the next missions capable of extending the climate data record. However, these missions have not yet been approved by space agencies. To address this concern, the OSTST made the following recommendation:

To continue the precision altimetry data record for monitoring and understanding global ocean circulation and sea level variability in relation to global climate variability, the OSTST recommends that Jason-3 be a high priority mission for NOAA and EUMETSAT and that, as recommended by the NRC Decadal Survey, the Surface Water and Ocean Topography Mission (SWOT) be a high priority mission for NASA. Jason-3 is vital for continuing the existing climate data record by bridging the gap between the present high-precision missions and future wide-swath altimetry missions, of which SWOT is the first.

The orbit choices for Jason-3 and SWOT were also discussed at the meeting. Regarding Jason-3, several practical advantages have been identified for changing to an orbit different from T/P, Jason-1 and Jason-2—i.e., shared launch, less radiation damage, etc. However, these advantages do not appear to outweigh the disadvantages—i.e., different sampling errors, absence of cross-calibration, time needed to build new reference surface for computing temporal changes, etc. The science team did not reach a consensus for a recommendation but agreed that ***if a change of orbit was to take place, all future precision altimetry missions must fly in the same new orbit.***

The science team was unanimous in regard to the impact of a sun-synchronous orbit for SWOT on meeting oceanography objectives: ***A sun-synchronous orbit will alias many surface and internal tidal components as well as all diurnally-varying signals into highly undesirable frequencies that overlap with important time scales for ocean circulation and climate studies. Therefore, such orbits for SWOT are not acceptable for meeting oceanography requirements.***

Future Meetings

Fu noted the evolution of altimetry from technical challenges to science challenges. He discussed the apparent disconnect between oceanographers and technologists in some of the splinter meetings. Although continuously pushing the envelope of measurement accuracy is always a charge to a measurement team like the OSTST, he suggested that technical splinters, such as those on sea-state bias, POD, and tides, need to evaluate the accomplishments already made and develop future foci to proceed. Topical science workshops—e.g., eddy science, general circulation, etc—are to be considered for future meetings. In any case, the balance between science and technical issues remains a challenge. Suggestions from the team members for the structure of future meetings are welcomed.

The next meeting is proposed to be held in France in November 2008, with the first results from OSTM/Jason-2 as the main objective. The meeting is being considered to coincide with the final symposium of the Global Ocean Data Assimilation Experiment (GODAE). A follow-on meeting in the United States with emphasis on OSTM/Jason-2 calibration/validation is being contemplated for April-May 2009. ■

Global 'Sunscreen' Has Likely Thinned, Report NASA Scientists

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

A new NASA study has found that an important counter-balance to the warming of our planet by greenhouse gases—sunlight blocked by dust, pollution and other aerosol particles—appears to have lost ground.

The thinning of Earth's "sunscreen" of aerosols since the early 1990s could have given an extra push to the rise in global surface temperatures. The finding, published in the March 16 issue of *Science*, may lead to an improved understanding of recent climate change. In a related study published recently, scientists found that the opposing forces of global warming and the cooling from aerosol-induced *global dimming* can occur at the same time.

"When more sunlight can get through the atmosphere and warm Earth's surface, you're going to have an effect on climate and temperature," said lead author **Michael Mishchenko** of NASA's Goddard Institute for Space Studies (GISS), NY. "Knowing what aerosols are doing globally gives us an important missing piece of the big picture of the forces at work on climate."

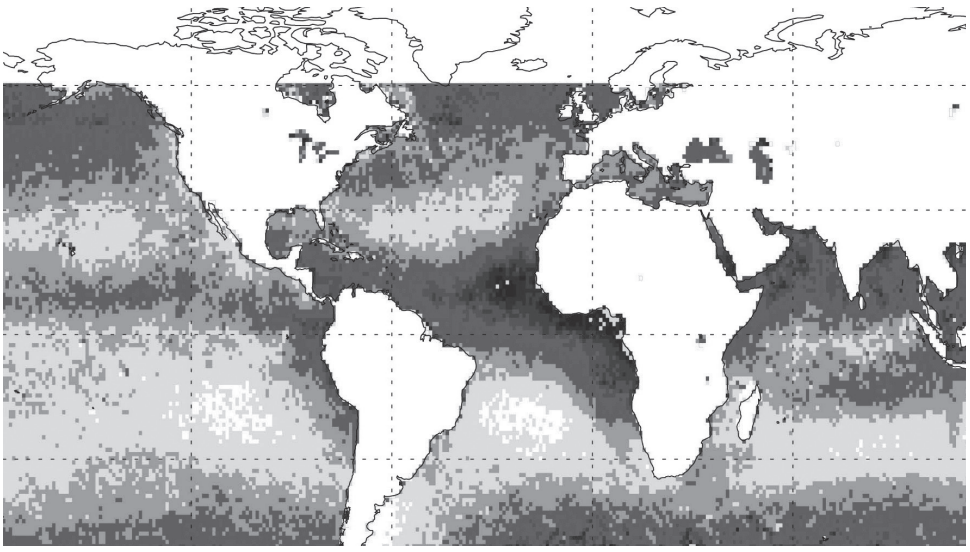
The study uses the longest uninterrupted satellite record of aerosols in the lower atmosphere, a unique set of global estimates funded by NASA. Scientists at GISS created the Global Aerosol Climatology Project by extracting a clear aerosol signal from satellite measurements originally designed to observe clouds and weather systems that date back to 1978. The resulting data show large, short-lived spikes in global aerosols caused by major volcanic eruptions in 1982 and 1991, but a gradual decline since about 1990. By 2005, global aerosols had dropped as much as 20% from the relatively stable level between 1986 and 1991.

The NASA study also sheds light on the puzzling observations by other scientists that the amount of sunlight reaching Earth's surface, which had been steadily declining in recent decades, suddenly started to rebound around 1990. This switch from a *global dimming* trend to a *brightening* trend happened just as global aerosol levels started to decline, Mishchenko said.

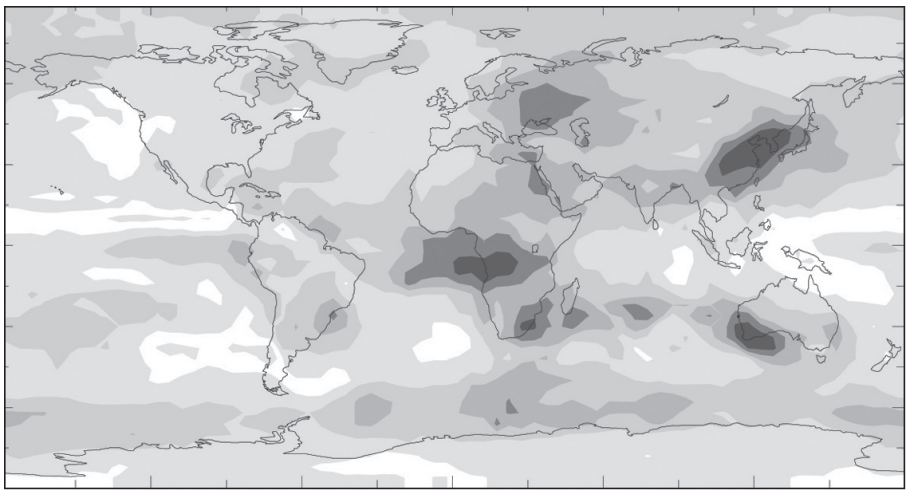
While the *Science* paper does not prove that aerosols are behind the recent dimming and brightening trends —changes in cloud cover have not been ruled out. Another new research result supports that conclusion. In a paper published March 8 in the American Geophysical Union's *Geophysical Research Letters*, a research team led by Anastasia Romanou of Columbia University's Department of Applied Physics and Mathematics also showed that the apparently opposing forces of global warming and global dimming can occur at the same time.

The GISS research team conducted the most comprehensive experiment to date using computer simulations of Earth's 20th-Century climate to investigate the dimming trend. The combined results from nine state-of-the-art climate models, including three from GISS, showed that due to increasing greenhouse gases and aerosols, the planet warmed at the same time that direct solar radiation reaching the surface decreased. The dimming in the simulations closely matched actual measurements of sunlight declines recorded from the 1960s to 1990.

Further simulations using one of the Goddard climate models revealed that aerosols blocking sunlight or



The average amount of dust, pollution, and other aerosol particles in the atmosphere has dropped since the 1990s. Global averages were relatively low in the period 2002–2005, shown here (highest aerosol levels in darkest shades). For color image please see *www.nasa.gov/centers/goddard/news/topstory/2007/aerosol_dimming.html*
Credit: NASA Global Aerosol Climatology Project



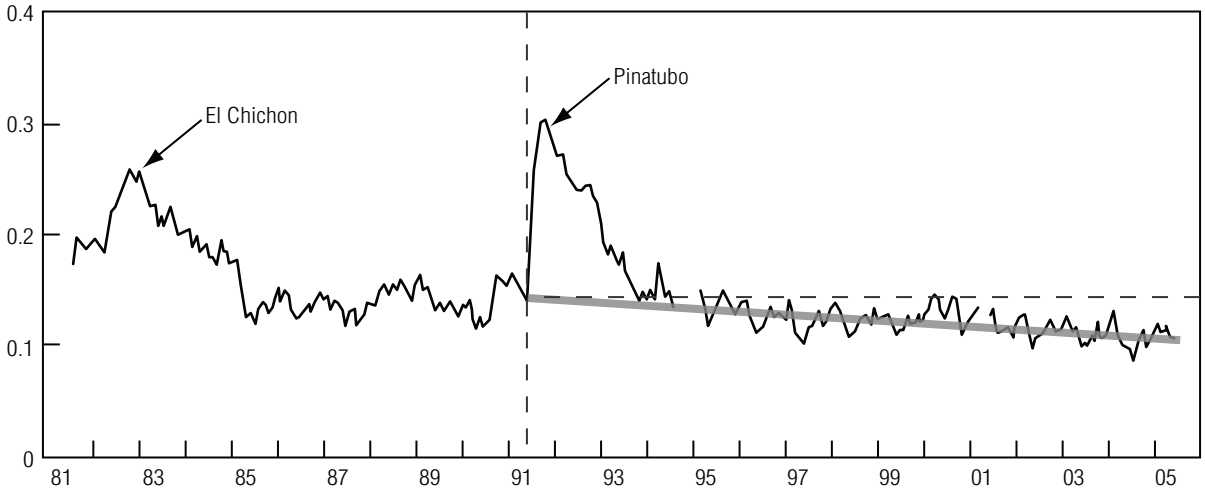
Computer simulations of Earth's climate over the entire 20th Century show the effect of airborne particles called aerosols: sunlight reaching the surface decreased over most of the globe (largest decrease shown in black). Some regions remained unchanged (white). There were very small areas in the eastern Pacific that showed a slight increase that cannot be detected in this black/white image. For color image please see *www.nasa.gov/centeres/goddard/news/topstory/2007/aerosol_dimming.html.* **Credit:** Anastasia Romanou, Columbia University.

trapping some of the sun's heat high in the atmosphere were the major driver in 20th-Century global dimming. "Much of the dimming trend over the Northern Hemisphere stems from these direct aerosol effects," Romanou said. "Aerosols have other effects that contribute to dimming, such as making clouds more reflective and longer-lasting. These effects were found to be almost as important as the direct effects."

The combined effect of global dimming and warming may account for why one of the major impacts of a warmer climate—the *spinning up* of the water cycle of evaporation, more cloud formation, and more rainfall—has not yet been observed. "Less sunlight reaching the surface counteracts the effect of warmer air temperatures, so evaporation does not change very much," said **Gavin Schmidt** of GISS, a co-author of the paper. "Increased aerosols probably slowed the expected change in the hydrological cycle."

Whether the recent decline in global aerosols will continue is an open question. A major complicating factor is that aerosols are not uniformly distributed across the world and come from many different sources, some natural and some produced by humans. While global estimates of total aerosols are improving and being extended with new observations by NASA's latest generation of Earth-observing satellites, finding out whether the recent rise and fall of aerosols is due to human activity or natural changes will have to await the planned launch of NASA's Glory Mission in 2008.

"One of Glory's two instruments, the Aerosol Polarimetry Sensor, will have the unique ability to measure globally the properties of natural and human-made aerosols to unprecedented levels of accuracy," said Mishchenko, who is project scientist on the mission. ■



Sun-blocking aerosols around the world have steadily declined (thick gray line) since the 1991 eruption of Mount Pinatubo, according to satellite estimates. The decline appears to have brought an end to the "global dimming" earlier in the Century. **Credit:** Michael Mishchenko, NASA

Gravity Measurements Help Melt Ice Mysteries

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

Greenland is cold and hot. It's a deep freezer storing 10% of Earth's ice and a subject of fevered debate. If something should melt all that ice, global sea level could rise as much as 7 m (23 ft). Greenland and Antarctica—Earth's two biggest icehouses—are important indicators of climate change and a high priority for research, as highlighted by the newly inaugurated International Polar Year.

Just a few years ago, the world's climate scientists predicted that Greenland wouldn't have much impact at all on sea level in the coming decades. But recent measurements show that Greenland's ice cap is melting much faster than expected.

These new data come from the NASA/German Aerospace Center's Gravity Recovery and Climate Experiment (GRACE). Launched in March 2002, the twin GRACE satellites circle the globe using gravity to map changes in Earth's mass 500 km (310 mi) below. They are providing a unique way to monitor and understand Earth's great ice sheets and glaciers.

GRACE measurements have revealed that in just four years, from 2002 to 2006, Greenland lost between 150–250 km^3 (36–60 mi^3) of ice per year. One cubic kilometer is equal to about 264 billion gallons of water. That's enough melting ice to account for an increase in global sea level of as much as 0.5 mm (0.019 in) per year, according to **Isabella Velicogna** and **John Wahr** of the University of Colorado, Boulder. They published their results in the scientific journal *Nature* last fall. Since global sea level has risen an average of 3 mm (0.1 in) per year since 1993, Greenland's rapidly increasing contribution can't be overlooked.

"Before GRACE, the change of Greenland's ice sheet was inferred by a combination of more regional radar and altimeter studies pieced together over many years, but GRACE can measure changes in the weight of the ice directly and cover the entire ice sheet of Greenland every month," says **Michael Watkins**, GRACE Project Scientist at NASA's Jet Propulsion Laboratory, Pasadena, CA. However, as anyone who has ever been concerned about his or her weight knows, a number on a scale is just the beginning. In the five years that GRACE has been flying, scientists have found ways to make the most of this new set of observations.

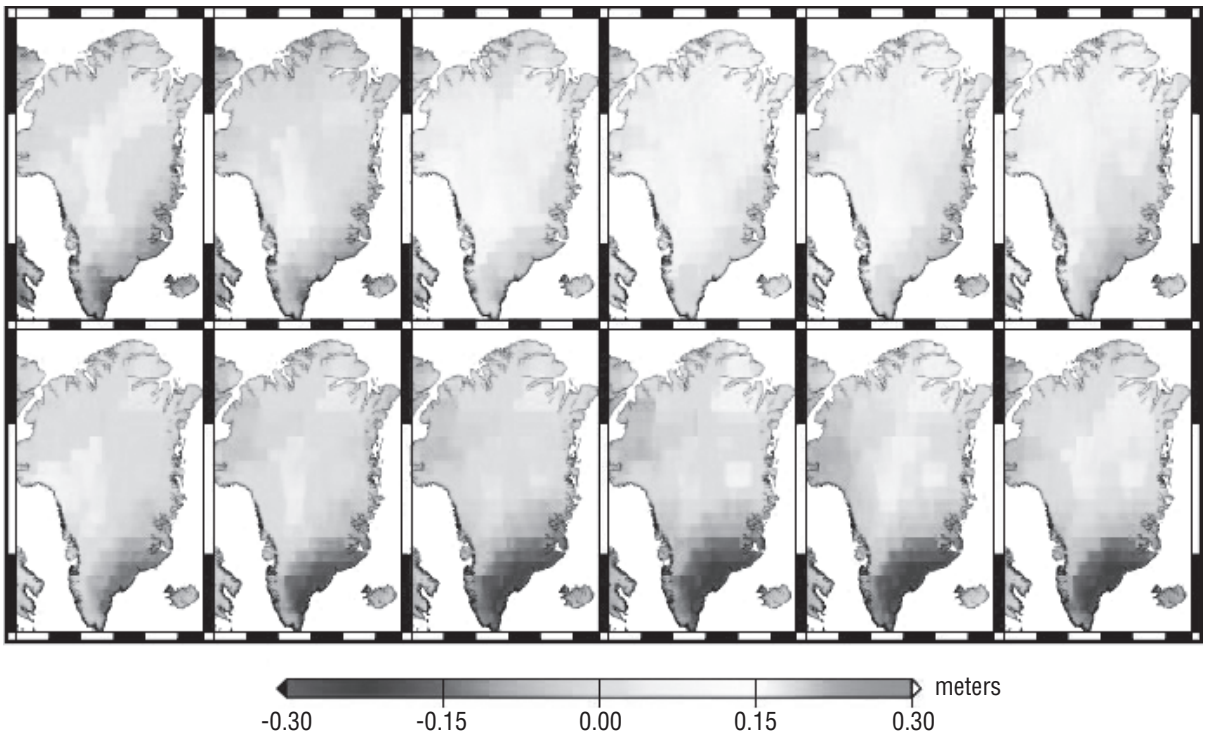
"GRACE has a big footprint," says Watkins. "We can locate regions of greatest loss, but we can't see individual glaciers." However, GRACE's spatial resolution is continually improving. In the most recent studies, he says, GRACE has observed large ice losses in the southeast of Greenland, while other areas, such as the west coast, have shown losses as well.

While Greenland is losing ice, it's also acquiring some new ice through precipitation. Scientists at NASA's Goddard Space Flight Center, used GRACE to determine that ice losses far surpass ice gains. A new way of analyzing the data allowed them to get a picture of regional changes. While snow added 60 km^3 (14 mi^3) of ice mass to Greenland's interior each year between 2003 and 2005, the low-lying coastal areas of Greenland lost nearly three times as much ice—172 km^3 (41 mi^3)—each year during the same period.

To confirm just how much of the mass GRACE detects in Greenland and Antarctica is due to snow and ice, scientists also have to determine the contributions from another source, Earth's changing crust. "When GRACE sees a change in polar gravity," says Watkins, "part of it is today's ice melt and part is what is called *post-glacial rebound*."

"A long time ago during the last Ice Age, this region was pushed down by even more snow and ice, and

Petermann Floating Tongue in north Greenland. **Credit:** NASA/JPL



Monthy changes in the mass of Greenland's ice sheet coverage observed by the GRACE satellites during 2005. Dark areas indicate areas of largest mass loss.

now this mantle wants to come back, or rebound," explains **Erik Ivins**, a JPL Earth scientist and GRACE Science Team member.

One way to look at the problem, says Ivins, is to imagine a bathtub filling up with water from a faucet but losing water from holes in the bottom of the tub. At the same time, the bathtub may be changing shape.

Ivins and his colleagues are refining the computer models used to understand and predict post-glacial rebound. It turns out that beneath the ice sheet covering Greenland, the mantle isn't changing the shape of the "bathtub" very fast. "This tells us that the large mass changes GRACE detects in the southeastern region of Greenland aren't due to post-glacial rebound," says Ivins.

As GRACE celebrates its fifth birthday and begins its extended mission, "we're getting the picture into better focus," says Watkins, "and we're going to have a new wave of discoveries. Improving the post-glacial rebound model is going to help, especially in Antarctica, where post-glacial rebound has a big effect on the gravity signal. We're also going to be able to pinpoint areas of loss and better understand how the losses change from one particular year to the next. This will tell us more about the types and mechanisms of ice mass loss so we can make better predictions in the future."

While GRACE provides a new and independent way to study Earth's ice sheets, it will take a combination of different tools, including laser altimeters, radar, and field studies, to sort out more clearly what's happening. "All technologies have different strengths and weaknesses," says Watkins. "GRACE is the new piece. It shows us the big picture, while other measurements look at a smaller scale. We need to use them all together."

"We have to pay attention," Velicogna adds. "These ice sheets are changing much faster than we were expecting. Observations are the most powerful tool we have to know what is going on, especially when the changes—and what's causing them—are not obvious." ■

NASA Models Show Trees Can Slow Increase of Atmospheric Carbon

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Converting marginal agricultural land to forests may help slow the increase of carbon in the atmosphere, according to model-based results obtained by NASA scientists using space-based Earth observations and a state-of-the-art ecosystem model.

Researchers found that on a national basis, converting marginal agricultural lands into forests has the potential to remove hundreds of millions of tons of carbon dioxide (CO_2) from the atmosphere every year. This conversion, known as *afforestation*, could be used to partially off-set carbon emissions produced by burning fossil fuels.

"In this study, we primarily wanted to know how much atmospheric carbon dioxide can be absorbed by plant growth over the next 20–30 years, if 25% or less of the United States' croplands and rangelands were planted with native tree species," said **Christopher Potter**, a scientist from NASA Ames Research Center, in California's Silicon Valley. "Our findings showed that at least one-fifth of annual fossil fuel emission of carbon in the U.S. can be offset by planting new forests," added Potter.

Using plants and soil to store atmospheric CO_2 could become part of our country's enhanced land use management. Generalized global estimates of stored carbon in afforested areas vary between temperate and tropical regions, but range as high as 4.5 billion tons of carbon per year, say scientists. These estimates are from model results, not actual measurements, and many questions, scientific and economic, must be answered before such land use practices are adopted.

Researchers collected *greenness* data from the Advanced Very High Resolution Radiometer (AVHRR) sensor on the NOAA Polar Operational Environmental Satellite (POES) and entered it into the NASA-Carnegie, Ames, Stanford Approach (CASA) carbon model at 8 km spatial resolution. The model generated three different national maps that showed estimates of the amount of carbon absorbed by plants growing in current forests, croplands and rangelands.

When the research was analyzed, the top five states identified as having a high carbon storage potential by converting croplands to newly developed forests were Texas, Minnesota, Iowa, Illinois, and Missouri. The top five states with potential for converting rangelands or pastures were Texas, California, Montana, New Mexico, and Colorado.

Research suggested that the southeast U.S. has the most favorable conditions for afforestation due to its subtropical climate; however, because the land area available for afforestation in those states is not as expansive as in places like Texas, none of the southeastern states made the list of having the greatest potential total state-wide carbon sinks. In addition, model results suggested that large areas of croplands in South Dakota, Minnesota, and Wisconsin showed potential for carbon management and shouldn't be underestimated.

Past studies show that managed land use practices can be very productive in removing carbon from the air, but variability in forest growth conditions across diverse climate, soil, water, and elevation zones make it difficult to predict outcomes. "If rainfall patterns change, for whatever reason, the risk of losing plants can go up in drought-stricken areas," noted Potter.

This work was made possible through funding by NASA as part of the long-term U.S. Department of Agriculture Northern Global Change Research Program, which is dedicated to understanding how human-induced and natural changes affect our global environment.

These and related studies appeared in the *Springer Science+Business Media* issues of *Climatic Change*, 2007. Christopher Potter was lead author. ■

Crimson Lady peach trees **Credit:** Robert Shenk, USDA.

NASA Data Show Earthquakes May Quickly Boost Regional Volcanoes

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

Scientists using NASA satellite data have found strong evidence that a major earthquake can lead to a nearly immediate increase in regional volcanic activity.

The intensity of two ongoing volcanic eruptions on Indonesia's Java Island increased sharply three days following a powerful, 6.4-magnitude earthquake on the island in May 2006. The increased volcanic activity persisted for about nine days.

"During this period, we found clear evidence that the earthquake caused both volcanoes to release greater amounts of heat, and lava emission surged to two to three times higher than prior to the tremor," said study lead author **Andrew Harris**, University of Hawaii, Honolulu. The research was recently published in the American Geophysical Union's *Geophysical Research Letters*.

While scientists have long debated whether earthquakes can trigger new volcanic eruptions, this study linked an earthquake to enhanced volcanic activity at two ongoing eruptions that were being closely monitored by satellite-based sensors on a daily basis.

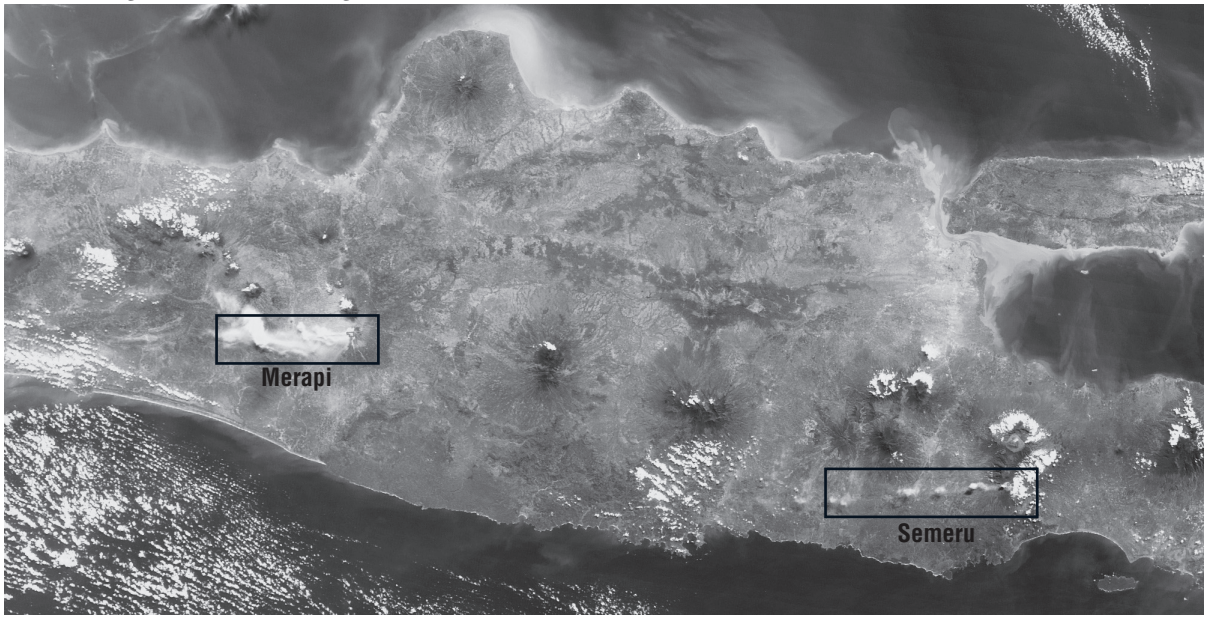
At the time of the earthquake, each volcano was being checked for changes in heat output by satellite sensors as part of a routine global "hot spot" monitoring effort that uses near real-time satellite data from NASA's Terra and Aqua satellites.

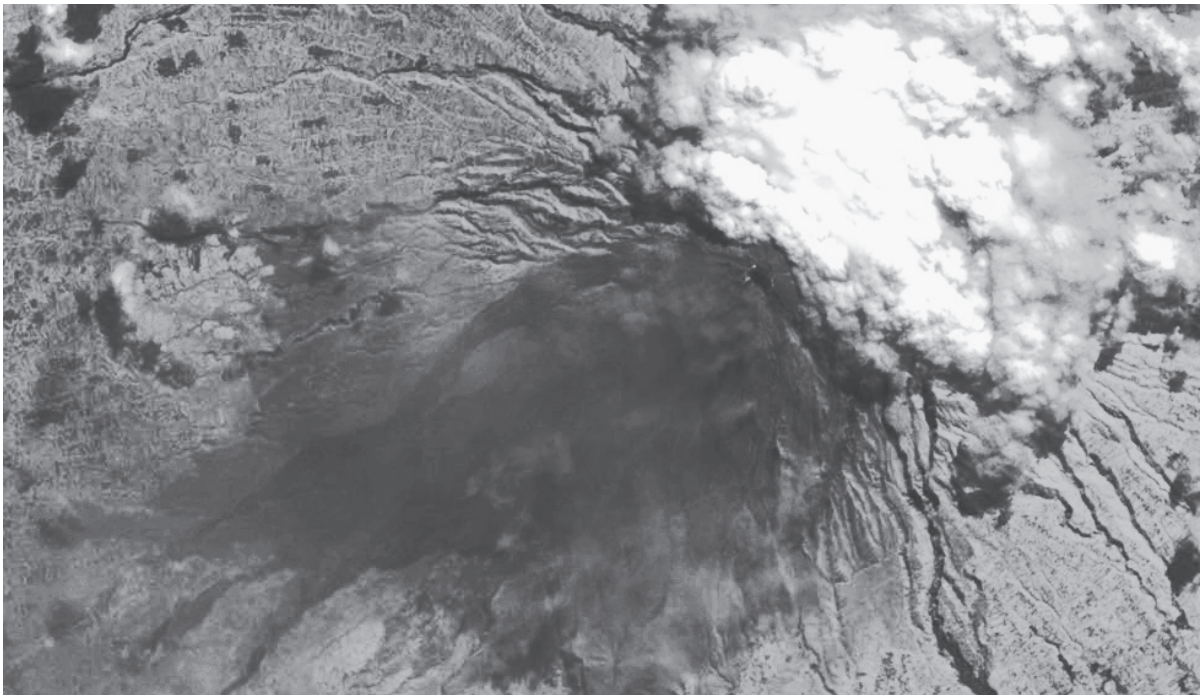
Maps of worldwide hot spot activity are created with data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on these satellites, pinpointing locations where surface temperatures are much hotter than their surroundings. The scientists combined these data with other details about the Indonesian volcanoes gathered by the satellites to analyze temperature and lava output rates at both volcanoes over a 35-day period spanning the earthquake.

The two volcanoes, Merapi and Semeru, are about 260 km (162 mi) apart and roughly 50 km (31 mi) north and 280 km (174 mi) east of the earthquake epicenter, respectively—see image below. Given these distances, the researchers believe underground stresses from the earthquake's seismic waves likely acted to pump *magma*—molten rock beneath the surface—into the conduit to the surface, ultimately increasing eruption rates.

"The responses at Merapi and Semeru lagged about three days behind the triggering earthquake, which may reflect the time it took the change felt by magma residing at deeper levels to be transmitted to the surface," said Harris.

The Merapi and Semeru volcanoes on Indonesia's Java Island released plumes of ash and steam on June 8, 2006. The plumes from Merapi (left) and Semeru (right) are shown in this image from the MODIS instrument on NASA's Terra satellite. **Credit:** NASA





This image of the Merapi volcano on June 6, 2006 shows ground surface and vegetation (light gray) underlying the volcanic plume (dark gray) and clouds (bright white), as captured by the ASTER instrument on NASA's Terra satellite. **Credit:** NASA/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team

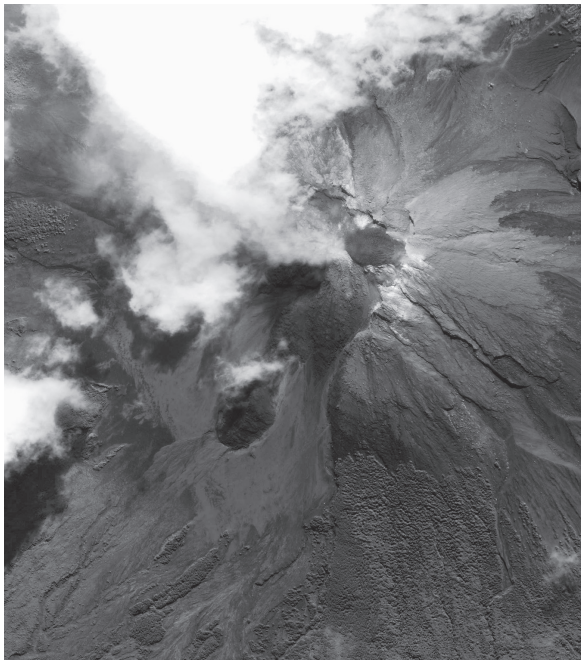
The researchers concluded that regional earthquake events have sufficient power to modify the intensity of activity at ongoing eruptions, although they may not always be able to trigger new volcanic eruptions.

They also noted that the Java earthquake had a significant influence on the volcanoes for a relatively short period of several days, suggesting that catching the effect of a quake on an eruption requires careful observation. "Eruptions must be closely and continuously monitored in the days immediately before, during and after an earthquake if we are to link any earthquake with enhanced volcanic activity," added Harris.

Satellite monitoring may be able to play a predictive role in eruptions, rather than just its more traditional responsive role, according to the study. Instruments on today's advanced satellites are providing new and considerably more data to help scientists better track and understand volcanic eruptions.

"The satellite data we have now—from MODIS, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and the Landsat-7 satellite—give us fresh insights into the behavior of volcanic systems around the entire globe," said Harris. "This worldwide perspective would not have been possible using ground-based sensors; there are too many unmonitored sectors and periods. We simply could not have uncovered our results without the continuous and global data provided by MODIS."

The researchers are currently reviewing older MODIS hot spot data, which extends back to 2000, to uncover additional earthquake-induced responses at erupting volcanoes in hope of identifying patterns that might be used to build a predictive model for forecasting earthquake-induced changes in activity at erupting volcanoes. ■



The Merapi volcano erupting on May 11, 2006—two weeks prior to the Java earthquake—as captured by Space Imaging's IKONOS satellite. A faint volcanic plume extends from the volcano's summit toward clouds. **Credit:** GeoEye

NASA Finds Sun-Climate Connection in Old Nile Records

Alan Buis, NASA Jet Propulsion Laboratory, Alan.D.Buis@jpl.nasa.gov

[Excerpted from a feature article at jpl.nasa.gov/news/features.cfm?feature=1319.]

A group of NASA and university scientists has found a convincing link between long-term solar and climate variability in a unique and unexpected source: directly measured ancient water level records of the Nile, Earth's longest river.

Alexander Ruzmaikin and **Joan Feynman** of NASA's Jet Propulsion Laboratory, together with **Yuk Yung** of the California Institute of Technology, have analyzed Egyptian records of annual Nile water levels collected between 622 and 1470 A.D. at Rawdah Island in Cairo. These records were then compared to another well-documented human record from the same time period: observations of the number of auroras reported per decade in the Northern Hemisphere.

Feynman said that while ancient Nile and auroral records are generally spotty, that was not the case for the particular 850-year period they studied. "Since the time of the pharaohs, the water levels of the Nile were accurately measured, since they were critically important for agriculture and the preservation of temples in Egypt," she said.

A similar record exists for auroral activity during the same time period in northern Europe and the Far East. People there routinely observed and recorded auroral activity, because auroras were believed to portend future disasters, such as droughts and the deaths of kings. "A great deal of modern scientific effort has gone into collecting these ancient auroral records, inter-comparing them and evaluating their accuracy," Ruzmaikin said.

The researchers found some clear links between the Sun's activity and climate variations. The Nile water levels and aurora records had two somewhat regularly occurring variations in common—one with a period of about 88 years and the second with a period of about 200 years. These findings have climate implications that extend far beyond the Nile River basin.

"Our results characterize not just a small region of the upper Nile, but a much more extended part of Africa," said Ruzmaikin. "The Nile River provides drainage for approximately 10% of the African continent. Its two main sources—Lake Tana in Ethiopia and Lake Victoria in Tanzania, Uganda and Kenya—are in equatorial Africa. Since Africa's climate is interrelated to climate variability in the Indian and Atlantic Oceans, these findings help us better understand climate change on a global basis."

So what causes these cyclical links between solar variability and the Nile? The authors suggest that variations in the sun's ultraviolet energy cause adjustments in a climate pattern called the Northern Annular Mode, that affects climate in the atmosphere of the Northern Hemisphere during the winter. At sea level, this mode becomes the North Atlantic Oscillation, a large-scale seesaw in atmospheric mass that affects how air circulates over the Atlantic Ocean. During periods of high solar activity, the North Atlantic Oscillation's influence extends to the Indian Ocean. These adjustments may affect the distribution of air temperatures, which subsequently influence air circulation and rainfall at the Nile River's sources in eastern equatorial Africa. When solar activity is high, conditions are drier, and when it is low, conditions are wetter.

Study findings were recently published in the *Journal of Geophysical Research*. ■

An aurora photographed over Fairbanks, Alaska, **Credit:** Jan Curtis

EOS Scientists in the News

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Stephen Cole, scole@pop600.gsfc.nasa.gov, NASA Earth Science News Team

NASA's AIM Mission Soars to the Edge of Space, April 25; *Associated Press, United Press International, CBS, Fox News*. NASA's Aeronomy of Ice in the Mesosphere (AIM) spacecraft, the first mission dedicated to the exploration of mysterious ice clouds that dot the edge of space in Earth's polar regions, was successfully launched, says a team of scientists led by **James M. Russell, III** (Hampton University).

Satellites Offer Sunny Outlook on Understanding Polar Climate, With Help of Cloudy Skies, April 24; *PhysOrg.com, Science Daily, Terra Daily*. Researchers including **Deborah Vane** (NASA JPL) and **Gail Skofronick Jackson** (NASA GSFC) recently completed a project to confirm what NASA satellites are telling us about how changes in clouds can affect climate in the coldest regions on Earth.

Rainy Day, But Still Dry Year in Southern California, April 21; *United Press International, Los Angeles Times, Washington Times*. The heaviest rain in about 11 months in sun-baked Southern California brought about one-half inch but did little to ameliorate the driest season on record, say scientists including **Bill Patzert** (NASA JPL).

*__NASA Data Show Earthquakes May Quickly Boost Regional Volcanoes__, April 10; *United Press International, Discovery.com, Earth & Sky Radio, LiveScience.com.* Researcher **Andrew Harris** (University of Hawaii) used NASA satellite data to uncover strong evidence that a major earthquake can lead to a nearly immediate increase in regional volcanic activity.

*__NASA Finds Arctic Replenished Very Little Thick Sea Ice in 2005__, April 3; *Pasadena Independent, SpaceRef.com.* A new NASA study led by **Ron Kwok** (NASA JPL) has found that in 2005 the Arctic replaced very little of the thick sea ice it normally loses and replenishes each year.

Did Dust Bust the 2006 Hurricane Season Forecasts?, March 28; *Scipps Howard News Service, United Press International, San Francisco Chronicle, USA Today.* A NASA study by **William Lau** (NASA GSFC) suggests that tiny dust particles may have foiled forecasts that the 2006 hurricane season would be another active one.

Reindeer and Snowflakes: NASA Helps During International Polar Year, March 28; *Science Daily.* NASA technology is contributing to International Polar Year efforts to identify snowflake shapes and enlist observations of indigenous reindeer herders in Norway, report scientists **Peter Wasilewski** (NASA GSFC) and **Nancy Maynard** (NASA GSFC).

Golden State Heating Up, New NASA/University Study Finds, March 28; *Reuters, KNBC-TV (Los Angeles), San Diego Union Tribune*. Average temperatures in California rose nearly 2° F during the second half of the 20th Century, with urban areas blazing the way to warmer conditions, according to a new study by **Bill Patzert** (NASA JPL), **Steve LaDochy** (California State University-Los Angeles), and **Richard Medina** (University of Utah).

*__Gravity Measurements Help Melt Ice Mysteries__, March 23; *Earth & Sky Radio, Science Daily, PhysOrg.com*. Researchers including **Isabella Velicogna**, **John Wahr**, **Michael Watkins,** and **Erik Ivins** (NASA JPL) used NASA's GRACE satellite to show that Greenland's ice cap is melting much faster than expected.

'Cool' Science: JPL Observes International Polar Year, March 21; *SpaceRef.com.* JPL will use NASA technology to help fulfill IPY research efforts by generating continental-scale mosaic maps of polar ice sheets, documenting glacier and ice shelf changes on the ground, and gathering information on glacier thickness in Greenland and Patgonia, says **Eric Rignot** (NASA JPL) and **Isabella Velicogna** (NASA JPL).

*__NASA Finds Sun-Climate Connection in Old Nile Records__, March 19; *Terra Daily.* **Alexander Ruzmaikin** (NASA JPL), **Joan Feynman** (NASA JPL), and **Yuk Yung** (California Institute of Technology) have found a link between long-term solar and climate variability in directly measured ancient water level records of the Nile.

Clearing the Air: NASA and EPA Work to Understand the Quality of the Air We Breathe, March 19; *Science Daily.* Scientists **Chris Hostetler**, **Russell DeYoung**, **Jay Al-Saadi**, **John Hair,** and **Rich Ferrare** (NASA LaRC) recently teamed with the Environmental Protection Agency for an intense field campaign to study air quality in the San Joaquin Valley in central California using instruments on aircraft, satellites, and at ground sites.

***Global 'Sunscreen' Has Likely Thinned, Report NASA Scientists**, March 15; *United Press International, Washington Times, Earth & Sky Radio.* A new study led by **Michael Mishchenko** (NASA GISS) found that an important counter-balance to the warming of our planet by greenhouse gases—sunlight blocked by dust, pollution and other aerosol particles—appears to have lost ground.

NASA Studies How Airborne Particles Affect Climate Change, March 14; *Earth & Sky Radio, SpaceFlight Now, SpaceRef.com.* Findings from the NASA-led Intercontinental Chemical Transport Experiment that examined how chemicals and pollution affect the ozone layer are offering new insight into the links between how natural and man-made aerosols warm or cool the Earth, report **Jens Redemann** (NASA ARC) and **Phil Russell** (NASA ARC).

NASA Studies True Colors of Evergreen Rainforests, March 12; *PhysOrg.com, Terra Daily.* NASA satellites reveal that Amazon forests are neither evergreen nor dependent on constant rain, and are capable of manufacturing their seasons, find researchers **Ranga Myneni** (Boston University) and **Rama Nemani** (NASA ARC).

Satellite Offers a Room With the Best View of Antarctica, March 7; *United Press International, Terra Daily.* Researchers including **Robert Bindschadler** (NASA GSFC) have woven together more than a thousand images from the Landsat 7 satellite to create the most detailed high-resolution map ever produced of Antarctica.

NASA's Advanced Technology Peers Deep Inside Hurricanes, March 6; *PhysOrg.com, Science Daily.* Determined to understand why some storms grow into hurricanes while others fizzle, scientists including **Jeff Halverson** (University of Maryland-Baltimore County) and **Ramesh Kakar** (NASA HQ) participated in a NASA-led field research campaign that examined budding hurricanes off the African coast.

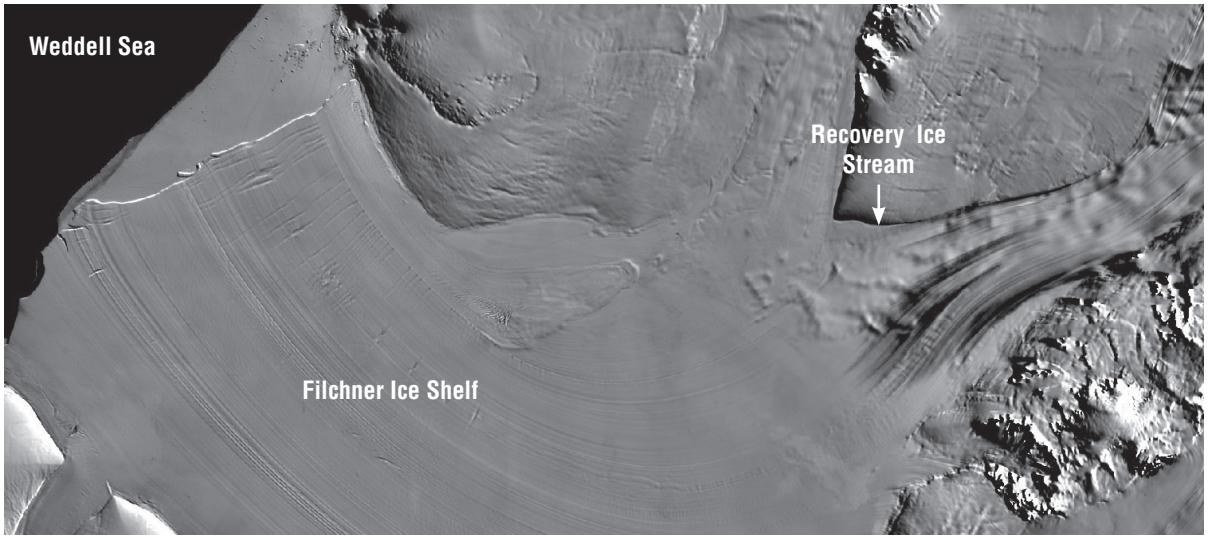
Antarctic Ice Sheet's Hidden Lakes Speed Ice Flow Into Ocean, May Disrupt Climate, March 5; *Terra Daily, Science Daily, Malaysia Sun.* Researchers **Chris Shuman** (NASA GSFC), **Robin Bell** (Columbia University), and **Michael Studinger** (Columbia University) have unearthed how water from a vast subglacial system contributes to the formation of ice streams and plays a crucial role in transporting ice from the remote interior of Antarctica toward the surrounding ocean.

Airborne Science in the Classroom: The Next-Best Thing to Being There, March 5; *Space Daily, Terra Daily*. **Larry Freudinger** (NASA Dryden) and other scientists developed a computer system to provide aircraft status and other information for a recent field campaign off the African coast that studied hurricanes.

*For more details see full *In the News* story in this issue.

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

A slab of ice larger than the continental United States smothers much of East Antarctica. Draining from the East Antarctic Ice Sheet is a river of ice nearly 800 km long. This stream, the Recovery Ice Stream, slides roughly 35 billion tons of ice into the ocean each year. In order to understand how large ice caps like the ones on Antarctica and Greenland will react to global warming, scientists must understand the basic dynamics of ice sheets, things like how fast they move, what causes them to speed up and slow down, and how much ice they carry to the ocean. In 2007, scientists reported that several large lakes lie beneath the Recovery Ice Stream and that when the ice stream flow over them, it speeds up. **Credit:** NASA MODIS Mosaic of Antarctica collection, provided by the National Snow and Ice Data Center.



Announcement

CERES Data Product Release

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center in collaboration with the Clouds and the Earth's Radiant Energy System (CERES) Science Team announces the release of the following data sets:

Synoptic Radiative Fluxes and Clouds (SYN)
- CER_SYN_Terra-FM1-MODIS_Beta3
- CER_SYN_Terra-FM2-MODIS_Beta3

Monthly Regional Radiative Fluxes and Clouds (AVG)
- CER_AVG_Terra-FM1-MODIS_Beta3
- CER_AVG_Terra-FM2-MODIS_Beta3

Monthly Zonal and Global Radiative Fluxes and Clouds (ZAVG)
- CER_ZAVG_Terra-FM1-MODIS_Beta3
- CER_ZAVG_Terra-FM2-MODIS_Beta3

The SYN/AVG/ZAVG products provide 1° gridded surface and atmospheric Fu-Liou radiative transfer fluxes consistent with observed CERES Top-of-Atmosphere (TOA) fluxes. This is a Level 3 version of the Cloud and Radiative Swath (CRS) and Monthly Gridded Radiative Fluxes and Clouds (FSW) Level 2 CERES data products and adds diurnal cycle improvements based on 3-hourly geostationary satellite data. It is the only CERES product with a package of surface Ultraviolet (UV) fluxes. This is the first release of this new product and is a *beta* product ready for evaluation but not yet sufficiently validated for use in journal publications. Like the ungridded CERES CRS data product, constrained fluxes are available for clear-sky and all-sky conditions at 70 hPa, 200 hPa, and 500 hPa; both constrained and untuned fluxes at surface and TOA for clear-sky, all-sky, pristine (no aerosols or clouds), and all-sky-no-aerosol conditions; allowing the user to infer various cloud and aerosol forcings. Unlike the CERES Monthly TOA/Surface Averages (SRBAVG) data product (1° monthly averages), these new products add:

a) 2-stream Shortwave (SW) [2/4 stream Longwave (LW)] radiative transfer for surface fluxes and constraints to TOA CERES fluxes, as well as aerosols and clouds derived from the Moderate Resolution Imaging Spectroradiometer (MODIS), and 3-hourly clouds derived from geostationary satellite data intercalibrated with MODIS.
b) 3-hourly synoptic fluxes (SYN), with fluxes averaged over 3 hour periods (not instantaneous fluxes as in FSW)—requested by climate and weather modeling groups for model validation studies.
c) The 3-hourly average fluxes (SYN) can be easily composited to daily, or any other time period by simple averaging.
d) Monthly (AVG) and zonal monthly (ZAVG) products are also provided for smaller data volumes.

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

HOW TO CONTACT US

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

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E-mail: *larc@eos.nasa.gov*
Web site: *eosweb.larc.nasa.gov*

NASA Science Mission Directorate – Science Education Update

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ELEMENTARY GLOBE

Elementary GLOBE is a series of five storybooks designed to help K-4 teachers integrate Earth science into their curriculum as they teach students to read and write. Each book focuses on a different Earth science topic as the main characters—Simon, Anita, and Dennis—explore the natural world. Storybooks and learning activities are correlated to national education standards in science, geography and math. Read more about *www.nasa.gov/audience/foreducators/k-4/features/F_Elementary_GLOBE.html*

REMOTE-SENSING APPLICATIONS FOR THE GEOSCIENCES WORKSHOP
July 10-11, 2007, University of Wisconsin–Madison

This workshop will equip science teachers with the knowledge and skills to utilize data and teach remote-sensing applications in four geoscience topics: meteorology, oceanography, geology, and climate change. Along with presentations by satellite experts, participants will engage in activities to identify cloud types, weather phenomena, ocean currents, and geological features in hands-on, break-out sessions. The workshop will culminate with a climate change session that highlights the connections between remote-sensing applications and Earth System Science. Lodging is provided to educators from outside of Dane County and college credit is available to all participants.

ATLAS OF SCIENCE LITERACY - VOLUME 2 NOW AVAILABLE

The American Association for the Advancement of Sciences has released its second volume of the *Atlas of Science Literacy* co-published by Project 2061 and the National Science Teachers Association. The atlas maps out science learning and science standards in a way that also charts how learning advances over time and grade levels. *Atlas 2* features all new maps for more than 40 essential topics including: Weather and Climate, Science and Society, The Nature of Mathematics, Human Development, Global Interdependence, and Explaining Evolution. More information is available at: *www.project2061.org/publications/atlas/default.htm.*

GLOBE WATERSHED PROJECT EDUCATOR WORKSHOP
August 7-9, 2007, Boulder, CO

Global Learning and Observations to Benefit the Environment (GLOBE) and the Geographic Data in Education (GEODE) Initiative at Northwestern University are looking for middle and high school science teachers to participate in an Earth System Science education project that connects students with real scientific data sets. Travel support may be available for a limited number of non-local participants.

The GLOBE Watershed Dynamics Project offers students the opportunity to conduct investigations on watershed behavior on local, regional, and national scales, using near real-time and archival data from a hydrologic database covering the entire continental U.S. Participants use M*y World GIS™,* a geographic information system (GIS) specifically designed for educational use to investigate the inter-relationships between precipitation, evaporation, and surface runoff on a regional and national scale. Emphasis will be placed on water availability in different regions of the country and how these variables change throughout the year.

NASA STUDENT OPPORTUNITIES PODCAST
www.nasa.gov/multimedia/podcasting/education/ED_NSO.html

Students talk about their NASA experiences—from competing in the Great Moonbuggy Race to working alongside scientists and engineers. Each episode also informs high school and college students about current NASA internships, fellowships, contests and other student opportunities.

NASA *ACT NOW* PAGE FOR EDUCATORS AND STUDENTS
www.nasa.gov/audience/foreducators/topnav/actnow/index.html

NASA Education's *Act Now* page highlights upcoming NASA opportunities available for teachers and students. The Educators section features information about upcoming workshops, grants, online activities, faculty fel-

lowships, and conferences in one location, making it easy for educators to find opportunities that interest them.

NASA has also created a new *Act Now* section just for students. *NASA and You* will inform students about upcoming NASA events, contests, internship opportunities, webcasts, and much more.

EARTH EXPLORERS

Anyone can be a scientist, no matter the challenges that may stand in the way. That's the message NASA communicates through its Earth Explorers and Space Science Explorers series, both of which appear on the NASA Web site. In an effort to show that a science career is a worthy and attainable goal, both series profile real-life scientists, young and old, with a variety of backgrounds and interests. Most articles are presented in three different versions according to reading level—one for grades 9–12 and up, one for grades 5–8, and one for grades K–4. Earth Explorers is located at *science.hq.nasa.gov/education/earth_explorers.* Space Science Explorers is located at *science.hq.nasa.gov/education/space_explorers.*

CERES Data Product Release

The Atmospheric Science Data Center (ASDC) at NASA Langley Research Center in collaboration with the CERES Science Team announces the release of the following data sets:

Single Scanner Footprint TOA/Surface Fluxes and Clouds (SSF)
- CER_SSF_Aqua-FM3-MODIS_Edition2B
- CER_SSF_Aqua-FM4-MODIS_Edition2B
- CER_SSF_Aqua-FM4-MODIS_Ed2B-NoSW*

Monthly Gridded TOA/Surface Fluxes and Clouds (SFC)
- CER_SFC_Aqua-FM3-MODIS_Edition2B
- CER_SFC_Aqua-FM4-MODIS_Edition2B

Edition2B differs from *Edition2A*, released in 2006 only in the values computed for the Surface Shortwave (SW) Model B Flux parameters. The errors that affected the SSF parameters "CERES downward SW surface flux - Model B" and "CERES net SW surface flux - Model B" of the *Edition2A* data set have been corrected in *Edition2B*. Similarly, the errors that affected the SFC parameters "SW SRF Model B Clear-Sky," "Net SW SRF Model B Clear-Sky," "SW SRF Model B Total-Sky," and "Net SW SRF Model B Total-Sky" of the *Edition2A* data set have been corrected in *Edition2B*. Otherwise, the *Edition2A* and *Editon2B* SSF and SFC data sets are identical.

* The CER_SSF_Aqua-FM4-MODIS_Ed2B-NoSW will be available this summer.

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

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Mail Stop 157D, 2 S. Wright Street Hampton, VA 23681-2199
Phone: 757-864-8656
E-mail: *larc@eos.nasa.gov*
Web site: *eosweb.larc.nasa.gov*

EOS Science Calendar

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

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

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

Global Change Calendar

June 25-29
32nd International Symposium on the Remote Sensing of the Environment (ISRSE), San Jose, Costa Rica.
URL: *www.cenat.ac.cr/simposio/welcome.htm*

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

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

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

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

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

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

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

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

September 11-13
The Second International Symposium on Arid Climate Change and Sustainable Development (ISACS), Lanzhou, China. URL: *http://www.gsma.gov.cn/reg/index1.asp*

October 10-11
Land and Vegetation Direct Readout Workshop, Unidad de seminarios of the Universidad Nacional Autonoma de México (UNAM), Mexico City. URL: *www.conabio.gob.mx/conocimiento/premota/doctos/location.html*

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

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

December 3-12
The Second International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering. Will be held on-line. URL: *www.cisse2007online.org/*

December 10-14
American Geophysical Union (AGU) Fall Meeting, San Francisco. URL: *www.agu.org/meetings/fm07/*

January 20-24
American Meteorological Society (AMS) Annual Meeting, New Orleans, LA. URL: *www.ametsoc.org/meet/annual/index.html*

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