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Editor's Corner

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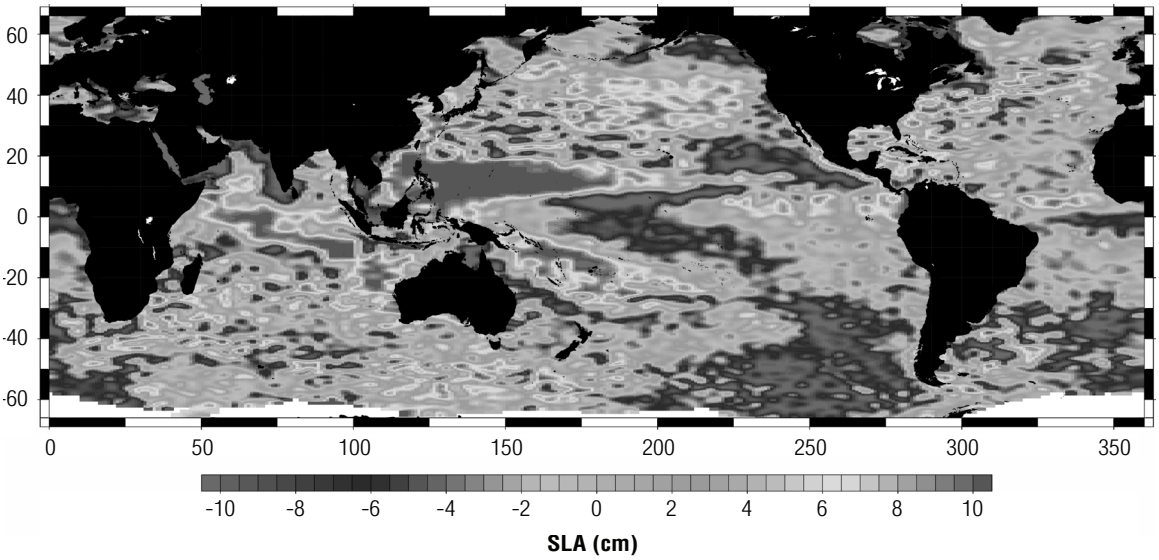
In recent issues of *The Earth Observer*, we presented the first two installments in a series of articles that we call *Perspectives on EOS*. In this series, we are asking a number of people who were closely involved with the EOS program to share their experiences and thoughts. We hope to provide some reflections on the program's past and present, as well as perspectives that have relevance to future Earth science programs. This month, we have a glimpse into what was going on in the very early days of the program—the *pre-history* of EOS—and how what we now know as EOS came to be. This insight comes from **Dixon Butler**, who was heavily involved in the creation and implementation of the EOS Program from late 1981 until 1995. My thanks go to Butler for taking the time to share his story with you; his article appears on page 4 of this issue.

continued on page 2

The Ocean Surface Topography Mission (OSTM)/Jason-2 launched June 20 and wasted no time getting to work. The satellite's radar altimeter collected its first data a little over 48 hours after launch, and within a month had already produced its first complete maps of global ocean surface topography, surface wave height, and wind speed.

The image shows mean sea-level anomaly data from the OSTM/Jason-2 for the period July 21–July 31. An *anomaly* is a departure from an average value. A higher-than-normal sea surface is usually a sign of warm waters below, while low sea levels often indicate cooler than normal temperatures. To view this image in color please visit: *photojournal.jpl.nasa.gov/catalog/PIA11197.*

NASA and the French Space Agency [Centre National d'Etudes Spatiales (CNES)] have collaborated on three missions since 1992: TOPEX/Poseidon (launched in 1992 and decommissioned in 2006); Jason-1 (launched in 2001 and still in operation); and now the OSTM/Jason-2 (launched in June). The continuous data record from these three missions helps scientists monitor how global sea level and the distribution of heat in the ocean changes over time. This information is used to monitor climate change and ocean circulation, and benefits society enabling more accurate weather, ocean and climate forecasts. Plans for Jason-3 are in the works with new OSTM/Jason-2 partners, NOAA, as lead agency, and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT).



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In our last issue, I mentioned the successful launch of the NASA-French Space Agency [Centre National d'Etudes Spatiales (CNES)] Ocean Surface Topography Mission (OSTM)/Jason-2 oceanography satellite. I can now report that it has wasted no time getting to work. The satellite's radar altimeter collected its first data a little over 48 hours after launch, and within a month, OSTM/Jason-2 had already produced its first complete maps of global ocean surface topography, surface wave height, and wind speed.

The map shown on the cover is an example of some of the early results from OSTM/Jason-2 and shows global ocean surface topography. This image shows mean sea-level anomaly (departures from average) data for the period July 21–July 31. A higher-than-normal sea surface is usually a sign of warm waters below, while low sea levels often indicate cooler than normal temperatures.

The new satellite and its predecessor, Jason-1, are now flying in formation in the same orbit approximately 55 seconds apart, making nearly simultaneous measurements that are allowing scientists to calibrate the new satellite's instruments. Once this period of calibration and validation is complete, OSTM/Jason-2 will remain in the orbit now occupied by Jason-1 and will continue the long-term record of ocean surface topography begun by TOPEX/Poseidon in 1992 and carried on by Jason-1. Meanwhile, Jason-1 will be moved to a new orbit beside OSTM/Jason-2 to provide additional measurements of ocean surface topography for as long as the older spacecraft remains healthy.

"These initial observations from OSTM/Jason-2 compare very closely to those of Jason-1," said **Lee-Lueng Fu**, OSTM/Jason-2 Project Scientist at NASA's Jet Propulsion Laboratory, Pasadena, CA. "To be able to collect such high-quality science data within a month of launch breaks previous records. It is also a direct reflection of how mature the field of satellite altimetry has become and of the seamless cooperation of our international team."

As OSTM/Jason-2 settles into its mission, NASA turns its attention to the launch of its next planned Earth science mission. Currently scheduled for a January 2009 launch from Vandenberg Air Force Base, the Orbiting Carbon Observatory (OCO) will join the afternoon satellite constellation (the A-Train) to make space-based measurements of column atmospheric carbon dioxide (CO_2) with the precision, resolution, and coverage needed to characterize the geographic distribution of CO_2 sources and sinks, and quantify their variability over the seasonal cycle. The observatory carries a single instrument designed to measure the absorption of reflected sunlight by CO_2 and molecular oxygen (O_2) (for light path correction and cloud and optically thick aerosol detection) at near-infrared wavelengths. These measurements are expected to improve our understanding of the processes that regulate atmospheric CO_2, thus enabling more reliable predictions

of CO_2 buildup and its impact on climate change. To learn more about this exciting new NASA mission, please read the article found on page 8 of this issue.

I can also report that Landsat 7 completed its 50,000th orbit on September 8. This orbit took the satellite along Landsat Worldwide Reference System (WRS) path 118 (between 252:0133-252:0312Z) with a ground track over Korea and southern China. A news brief commemorating the orbit can be found on the Landsat website at—*landsat.gsfc.nasa.gov/news/news-archive/news_0165.html*—along with an image collected during the milestone orbit by the Enhanced Thematic Mapper-Plus (ETM+) sensor aboard Landsat 7 (see image below).

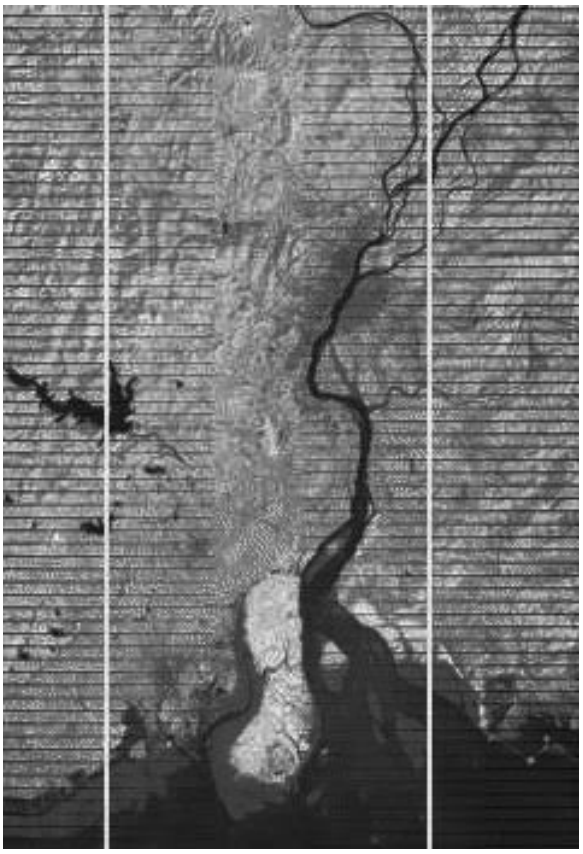
I would also like to take this opportunity to welcome NASA Goddard's new Center Director, **Rob Strain**. He succeeds **Edward Weiler**, who was named Associate Administrator of NASA's Science Mission Directorate in May. Strain comes to Goddard from the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, MD where he served as Head of the Space Department.

NASA Administrator **Michael Griffin** had high praise for the new Director. *"My association with Rob Strain spans years of shared experiences in both industry and at the Applied Physics Laboratory,"* said Griffin. *"He is one of the finest managers I know, and complements those talents with equally impressive 'people skills' and an unbending sense of personal integrity. I am truly looking forward to his addition to a superbly talented NASA management team."*

Prior to joining APL, Strain held executive positions with Axiom Corporation, Orbital Sciences Corporation, and Fairchild Space and Defense Company. Strain assumed his duties at Goddard on August 4; the NASA Earth science community looks forward to future interactions with the new Center Director.

NASA held a media teleconference on Monday, September 8, to present the results of a study on how the U.S. government currently uses Earth science information to manage resources and protect public health. This report, the latest in a series of synthesis assessment products from the U.S. Climate Change Science Program (CCSP), addresses various aspects of the country's highest priority research, observation, and decision-support needs. The study examines the decision-support tools that government agencies use to make predictions and forecasts in such areas as agricultural productivity, air quality, renewable energy resources, water management, and the prevention of vector-borne disease. It also probes the extent to which these decision-making tools are used to evaluate future impacts of climate change. The full report, *Uses and Limitations of Observations, Data, Forecasts, and Other Projections in Decision Support for Selected Sectors and Regions*, can be downloaded from: *www.climatescience.gov/Library/sap/sap5-1/final-report/*. (Other CCSP reports can be found via the same link.)

In closing, it's a pleasure to report that Earth science missions were well represented at *LaunchFest*—a NASA Goddard celebration of current and soon-to-be-launched science missions that took place on September 13. According to the Goddard Public Affairs Office, approximately 13,000 visitors toured the campus that day. Earth science activities included exhibits from Aqua; Aura; Glory; Ice, Clouds, and land Elevation Satellite (ICESat); Landsat; Landsat Data Continuity Mission (LDCM); the National Polar-orbiting Operational Environmental Satellite (NPOESS) Preparatory Project (NPP); and the Soil Moisture Active/Passive (SMAP) satellite. In addition, EOS science and outreach staff gave a number of live presentations on relevant Earth science topics. Thanks go out to all of those who were involved in making the event so successful. ■



Landsat 7's 50,000th orbit took the satellite over China and Korea. The Yalu River which divides China and North Korea can be seen above in an image acquired on that orbit. [This image falls on WRS-2 Path 118 Row 32, acquired on September 8, 2008.]

feature articles

The Early Beginnings of EOS: "System Z" Lays the Groundwork for a Mission to Planet Earth

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In 1978, NASA had sold the idea that the Shuttle, a reusable manned launch vehicle, would be used to deliver payloads to low Earth orbits, including sun-synchronous orbits, in a cost-effective manner. There is skepticism in the science community as to whether this can actually be accomplished.

This article continues our *Perspectives on EOS* series. It is our intention that these articles, written by "key players" who were actually present and played, or continue to play, key roles in the development of NASA's Earth Science Programs, will help shed light on the history of EOS while providing some lessons-learned for future Earth observing missions.

From late 1981 until 1995, **Dixon Butler** was one of those "key players." He played an important role during the formation of what we now know as the Earth Observing System (EOS). Butler was Program Scientist of EOS, and led the mission planning after its initial *System Z* version. Once EOS began development, he headed the division at NASA Headquarters responsible for developing the EOS Data and Information System (EOSDIS) and the operations and data systems for all NASA's Earth Science missions after launch. Following are some of his memories from those early years. Our thanks go to Butler for taking the time to share his story with you. We think you will enjoy it!

Let's think back 30 years…it is 1978…NASA is in the post-Apollo era…there has not been a manned spaceflight since the last Apollo–Soyuz mission in 1975…the Agency's primary focus at this time is on building and launching the Space Shuttle and resuming manned spaceflight missions. There are several somewhat different programs scattered around the Agency doing Earth science research, but there is no formal integrated Earth science program as we know it today. NASA had sold the idea that the Shuttle, a reusable manned launch vehicle, would be used to deliver payloads to low Earth orbits, including sun-synchronous orbits, in a cost-effective manner. There is skepticism in the science community as to whether this can actually be accomplished.

In 1978, NASA is headed by an oceanographer and forms an oceans program under the leadership of **Stan Wilson**. Satellite oceanography is the "missing piece" needed to complete the overall program of studying Earth using satellites. This program already includes the study of weather, climate, severe storms, air quality, stratospheric ozone depletion (comprising environmental observations), renewable and non-renewable resources (constituting Earth observations), and limited amounts of terrestrial ecology (included in the NASA Life Sciences Program).

As Space Shuttle development proceeds, there is some discussion among NASA planners of a space platform to be assembled in orbit from modules, each of which would fill the Shuttle cargo bay. Meanwhile, although Nimbus 7 is providing a collection of seemingly disparate measurements, the various fragmented Earth science programs face many challenges and setbacks. Landsats 4 & 5 are experiencing cost overruns; Seasat has died after 99 days of operations; and the Upper Atmosphere Research Satellite (UARS) and the Ocean Topography Mission (TOPEX) are on-hold awaiting *new starts*. NASA, NOAA, and the Navy plan a major leap forward from Seasat with the National Oceans Satellite System (NOSS). It would have been the largest Earth observation satellite mission ever, but in the wake of **Ronald Reagan** becoming President, there is a political need to balance the largest peacetime military build-up with some cost savings, and the Navy decides to cancel NOSS.

Amidst all these challenges, *magic* begins to happen. **The *seed* of the idea that would become Earth System Science as we know it today (through the report of the Bretherton Committee) is ready to fall in good soil and sprout.** After almost a year in office, the Administration finally appoints new leadership for NASA, and **Bert Edelson**

becomes Associate Administrator for Space Science and Applications. Dr. Edelson believes that the future of geosynchronous communications satellites lies in large-size platforms. The question he wrestles with is how to motivate interest in and begin development of these larger satellites. Dr. Edelson realizes that large platforms in low Earth orbit could be of use in Earth science and he asks **Pitt Thome**, former Director of the Earth Observations Division at NASA Headquarters, to pull together a group to study the idea.

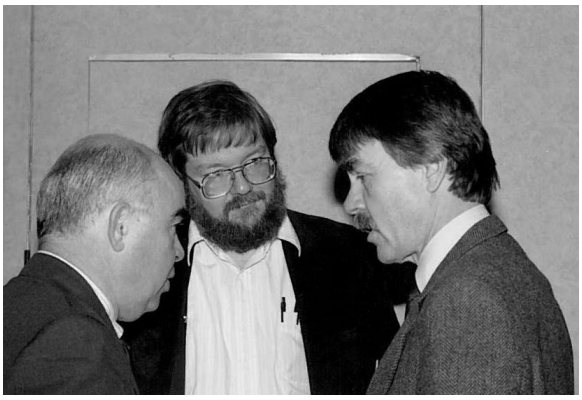
I was Executive Secretary of that committee, and our story is an important part of how EOS came to be. I would like to share a bit of that story with you.

The group assembled included the program managers from the three different divisions at NASA Headquarters who had some involvement with Earth observations as well as line managers from three NASA centers—Goddard, the Jet Propulsion Laboratory (JPL), and Stennis.

The mental climate of the early Reagan years was "the sky's the limit." Dr. Edelson named the effort *System Z* and had **Alex Tuyahov** work a parallel effort called *System Omega* to market the observations to the Department of Defense. The first thing that the *System Z* committee did at its initial meeting was to explain to one another the observing interests of the individual fields. The second meeting was held at JPL, and it was unclear whether or not this dissimilar set of interests could come together into a single mission. After a long day of meetings, I was in my hotel room thinking back on all I had heard when the now obvious thought dawned on me: *water connects all the Earth science fields*. I conceived of a payload of six large observing instruments including a weather radar, a large passive microwave sensor, visible and infrared imagers of high and moderate resolutions, etc.

After a long day of meetings, I was in my hotel room thinking back on all I had heard when the now obvious thought dawned on me: ***water connects all the Earth science fields****. I conceived of a payload of six large observing instruments including a weather radar, a large passive microwave sensor, visible and infrared imagers of high and moderate resolutions, etc.*

The next morning I presented this grandiose concept to my fellow committee members, and they immediately embraced the idea. Much to my surprise, they then asked me for the rest of the payload concept, and a day later I presented a payload concept with a total of 19 instruments in three groups. At subsequent meetings, the committee dealt with space platform design concepts and developed our *vugraphs* (no *Power Point* or Internet access back then!) for presenting the *System Z* idea to NASA management. Dr. Edelson was pleased with our effort and arranged for Pitt Thome to present the idea to the NASA Administrator. I was not able to attend the presentation, but afterwards I was told that the Administrator, who had known Dr. Edelson since their days together at the Naval Academy, turned to his old friend and told him to stop trying to undermine the Space Station effort. However, he gave Dr. Edelson permission to proceed with planning provided he didn't read about it in the aerospace press.



Left to Right: Shelby Tilford, Dixon Butler, and Stan Wilson in March 1990 at an EOS Investigators Working Group meeting. (This photo originally appeared in the March 31, 1990 issue of *The Earth Observer*—Volume 2, Number 3.)

Things were starting to look up for Earth science—Landsat 4 launched, TOPEX got its new start [becoming TOPEX/Poseidon, a partnership with the French Space Agency Centre National d'Etudes Spatiales (CNES)], and UARS got a partial new start. There was a reorganization at NASA Headquarters, and **Shelby Tilford** became the Director of a division that now included all the previously scattered components of Earth science. *System Z* planning proceeded with a $3 million annual budget and project offices at both Goddard and JPL. I was put in charge as Program Scientist in a wonderful partnership with Alex Tuyahov as Program Manager and **Dr. Richard Hartle** as Project Scientist at Goddard.

The report of the EOS group had at its heart a set of five principles that govern priorities in Earth science and should continue to be our guiding principles 30 years later. The five principles flow from the fact that we only have one Earth to study and generally cannot conduct controlled experiments. The guiding philosophy: take today's data today—it won't be available tomorrow.

Recognizing that *System Z* had been totally an in-house effort that was unlikely to gain support from the broader science community, I decided to start over with a working group of outside scientists. I went to my colleagues to recommend group members who were sufficiently senior so as to be recognized as speaking for their areas of science, but receptive to the idea of working across disciplinary lines. I also insisted on "no jerks" (I actually used a somewhat more vernacular term.) The initial meeting demonstrated a clear lack of representatives from the ecology community. To remedy this, we decided to expand the group to 20 folks, and met in Easton, MD. The meeting consisted of several days during which each member explained his area of research to the group.

The third meeting was held on Lake Tahoe at the suggestion of **Paul Zenke** of the University of California at Berkeley, who knew California like the back of his hand. Roughly five members of the committee got to talking in the evening—while relaxing in a hot tub. The next morning, led by **Ray Arvidson**, they quickly took charge of the meeting, told me as chairman to be quiet, and presented their ideas for *System Z*. No one in this small group had any knowledge of the results of the earlier in-house study and payload concept, but I immediately recognized what they presented as essentially the same concept we had come up with. Some of the proposed instruments were different (in fact, satellite weather radar was missing), but the concept was essentially the same.

All that remained was for the committee to write a report, and at our fifth meeting in Columbia, MD, Dr. Arvidson presented the idea to Dr. Tilford on behalf of the group, and Tilford bought it. **Robert Watson** was also at the meeting and began to raise substantial criticisms. For the only time I can remember in my long association with these two men, Dr. Tilford told Dr. Watson to stop.

The committee insisted on changing the name to Earth Observing System or EOS. There was a Space Shuttle experiment called Electrophoresis Operations in Space, and they had trademarked the acronym EOS. Enlisting my oldest son Bill, who was 12 at the time, I advanced the idea that the mission be officially called *Eos*, named after the goddess of the dawn and mother of the four winds in Greek mythology. With the help of the relevant story *xeroxed* (no *Google* searches back then!) from my son's book of Greek myths, I succeeded in convincing Dr. Edelson that this was a reasonable way around the trademark issue, and *Eos* became the name. Several years later, NASA attorneys determined that Earth Observation System was an early name for Landsat and that the agency had prior use of EOS as an acronym, thus freeing *Eos* to be EOS.

The report of the EOS group had at its heart a set of five principles that govern priorities in Earth science and should continue to be our guiding principles 30 years later. The five principles flow from the fact that we only have one Earth to study and generally cannot conduct controlled experiments. **We must observe the system as comprehensively as we can and study the patterns and their changes in order to learn and understand the Earth system, particularly the energy, water, and biogeochemical cycles that constitute this system.** So the priority is: *take today's data today*—it will not be available in the future. Continuity in observations became a critical element of EOS, but the continuity elements of EOS were dropped during a period when NASA was more focused on development of new technologies than on leading the efforts to understand our home planet. I believe that many of the troubles facing Earth observations today stem from this mistake.

In conclusion, I would note that the existence of EOS as a clear and compelling plan for a science endeavor aided the Bretherton Committee in finally reaching its wonderful conclusion. It thereby helped to bring the U.S. Global Change Research Program into existence. Also, with the EOS *new start* in fiscal year 1991, the annual budget for Earth science at NASA rose to more than three times its prior maximum in real dollar terms. **EOS also engendered a spirit of purpose that uplifted and energized the work of almost all of those involved, and it was a source of considerable joy for me.** ■

The original *System Z* concept called for three different payloads (in the Space Shuttle) each with differing scientific emphasis. Note the proposal envisioned using astronauts to assemble and service the platforms, perhaps in a manner similar to what is now done with the Hubble Space Telescope. Also note that the proposal anticipates the need for developing a data system to process the information returning from *System Z*.

Payload 1: Emphasis on water cycle, land use/cover, cryosphere, biomass dynamics, continental geology
Payload 2: Emphasis on biogeochemical cycles other than water, atmospheric chemistry
Payload 3: Emphasis on climate, atmospheric and oceanic circulation

Representative Instruments

- High Resolution Imaging Spectrometer
- Advanced Synthetic Aperture Radar
- Lidar Facility

Potential Roles of Man

- On-orbit assembly for system growth
- On-orbit servicing for long-term operation and payload capability evolution
- System evolution consistent with anticipated growth of man-tending capability.

Observational Platform/System Requirements

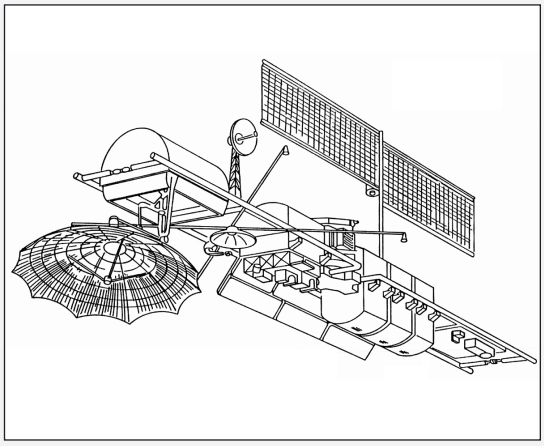
- Metric tons of payload weight
- Tens of kilowatts of power
- Hundreds of megabits per second (MBPS) of data
- Large articulated antennas and high precision pointing platforms
- On-orbit servicing

Data System Requirements

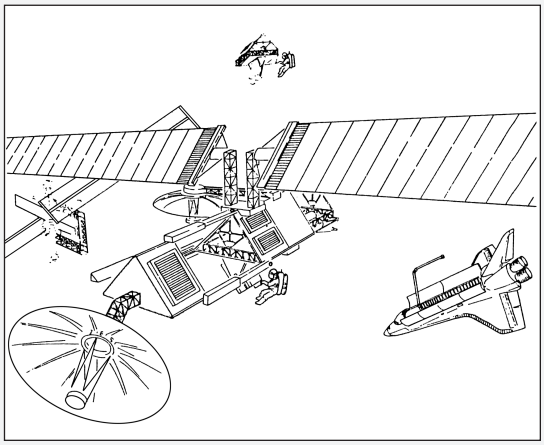
- Typical data relay rates 100-30 0 MBPS
- Direct rates 100-1000 MBPS
- Onboard storage capacity up to 10^{12} bits
- Processing adequately supported by hardware technology in the 90s timeframe (space configuration and qualification required).
- Significantly different approach to software development and protocol definition must be pursued.

Distributed Command and Control

- Users given direct control over instruments (remote operation).
- Status data and command link maintained continuously through Tracking and Data Relay Satellite System (TDRSS) MA system (important for control of pointed instruments).
- Data sent to users either direct or through TDRSS and ground network.



A schematic drawing of one of the proposed System Z platforms.



Drawing depicting Space Shuttle astronauts and System Z platform.

Credit: Mark Abbott [Oregon State University]—Abbott was a member of the Investigator Working Group of the Earth Observing System, and had an archived copy of a presentation that **Bert Edelson** [NASA Headquarters (HQ)], **Shelby Tilford** [NASA HQ], **James Dunne** [NASA/JPL], **Donald Drueger** [NASA GSFC], and **Paul Mowatt** [NASA GSFC] gave on *System Z* back on February 18, 1983! Abbott was nice enough to scan the content and provide it to *The Earth Observer* Staff for use in this article. The two platform diagrams and the information in this sidebar were gleaned from that presentation.

feature articles

The Orbiting Carbon Observatory (OCO):

Watching the Earth Breathe—Mapping Carbon Dioxide from Space

David Crisp, NASA Jet Propulsion Laboratory, david.crisp@jpl.nasa.gov
Chip Miller, NASA Jet Propulsion Laboratory, charles.e.miller@jpl.nasa.gov
Karen Yuen, NASA Jet Propulsion Laboratory, karen.yuen@jpl.nasa.gov

OCO will make space-based measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize the geographic distribution of CO_2 sources and sinks and quantify their variability over the seasonal cycle.

Background on Carbon Dioxide and OCO

Carbon dioxide (CO_2) is the principal man-made greenhouse gas and the primary atmospheric component of the global carbon cycle. Precise ground-based measurements of CO_2 made since the late 1950s indicate that the atmospheric CO_2 concentration has increased from ~310 to over 380 parts per million (ppm) over this period [*1*]. Interestingly, comparisons of these data with CO_2 emission rates from fossil fuel combustion, biomass burning, and other human activities indicate that only about half of the CO_2 that has been emitted into the atmosphere during this period has remained there. Surface *sinks* in the land biosphere or oceans have apparently absorbed the remaining amount [*1, 2, 3*]. These measurements also show that despite the steady long-term growth in the CO_2 abundance, the atmospheric CO_2 buildup varies dramatically from year to year in response to smoothly increasing emission rates. The ground-based CO_2 monitoring network does not have the spatial resolution, coverage, or sampling rates needed to identify the natural sinks responsible for absorbing this CO_2 or the processes that control how their efficiency changes from year to year.

NASA's Orbiting Carbon Observatory (OCO)—spacecraft drawing shown left—is an Earth System Science Pathfinder (ESSP) mission that is currently being developed to address these issues [*4*]. OCO will make space-based measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize the geographic distribution of CO_2 sources and sinks and quantify their variability over the seasonal cycle**.** The Observatory is scheduled for a January 2009 launch from Vandenberg Air Force Base in California on a *Taurus 3110* launch vehicle. During its two-year nominal mission, OCO will fly in a circular, 438 mi (705 km) altitude, near-polar, sun-synchronous orbit that provides global coverage of the sunlit hemisphere with a 16-day ground-track repeat cycle. The observatory carries a single instrument designed to measure the absorption of reflected sunlight by CO_2 and molecular oxygen (O_2) at near infrared (NIR) wavelengths. Co-boresighted spectroscopic measurements of the CO_2 and O_2 column abundance will be analyzed to retrieve spatial variations in the column averaged CO_2 dry air mole fraction (X_{CO_2}) where X_{CO_2} measurements have random errors and systematic biases no larger than 0.3-0.5% on regional scales. These measurements are expected to improve our understanding of the nature and processes that regulate atmospheric CO_2, enabling more reliable forecasts of CO_2 buildup and its impact on climate change.

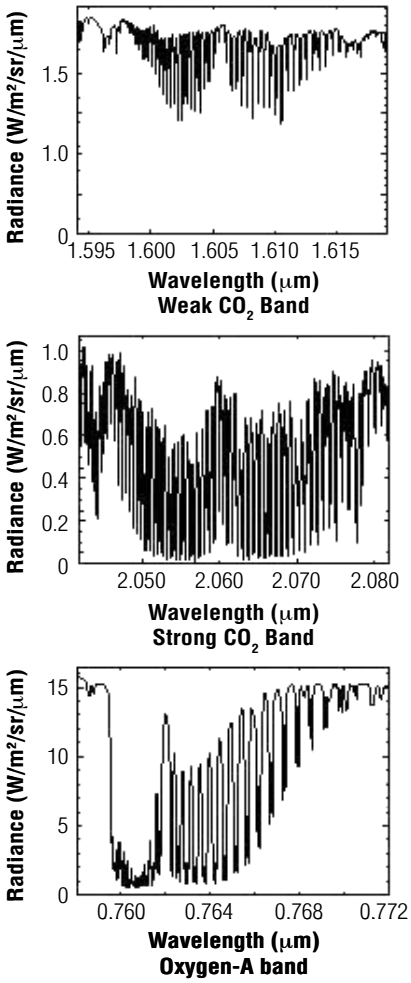
How Does OCO Work?

The OCO spectrometers measure sunlight reflected off the Earth's surface. Carbon dioxide and molecular oxygen molecules in the atmosphere absorb light energy at very specific colors or wavelengths. So, the light that reaches the OCO instrument will display diminished amounts of energy at those characteristic wavelengths. The OCO

instrument employs a *diffraction grating* (like the back of a compact disc) to separate the inbound light energy into a spectrum of multiple component colors. The *reflection gratings* used in the OCO spectrometers consist of a very regularly spaced series of grooves that lie on a very flat surface.

OCO mission designers selected three specific NIR wavelength bands to help them measure atmospheric CO_2. The OCO instrument measures intensity over all three of these bands at the same location on the Earth's surface at the same instant: a *weak CO_2 band* centered around 1.61 µm, the *Oxygen (O_2)-A band* at 0.76 µm, and *a strong CO_2 band* centered around 2.06 µm. Each of the three selected wavelength bands provides a specific contribution to measurement accuracy.

The strong CO_2 band was chosen because it provides a second and totally independent measure of the CO_2 abundance. The 2.06 µm band spectra are very sensitive to the presence of aerosols. The ability to detect and mitigate the presence of aerosols enhances the accuracy of X_{CO_2}. The 2.06 µm band measurements are also sensitive to variations in atmospheric pressure and humidity along the optical path.



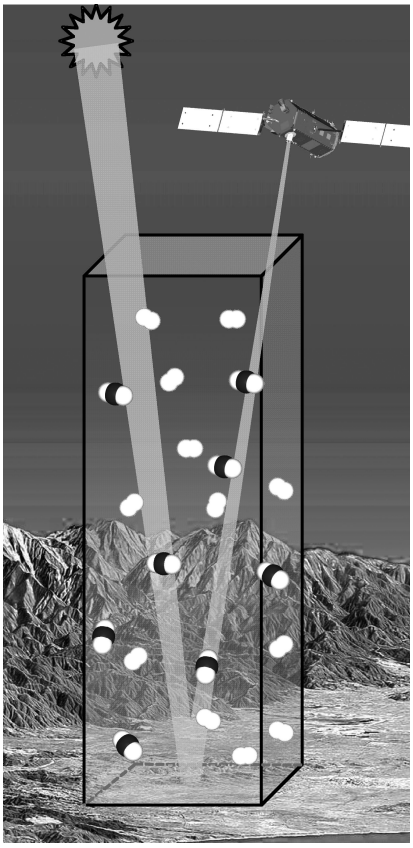
The three graphs show the near-infrared wavelength bands chosen to help OCO measure atmospheric CO_2. The bands were chosen because each wavelength band provides a specific contribution to the CO_2 measurement accuracy. (see article text for details)

The weak CO_2 band was chosen because it is most sensitive to the CO_2 concentration near the surface. Since other atmospheric gases do not absorb significant energy within this spectral range, band measurements at 1.61 µm are relatively clear and unambiguous.

Accurate derivation of X_{CO_2} using space-based readings of the CO_2 absorption requires comparative absorption measurements of a second atmospheric gas. The concentration of molecular oxygen (O_2) is constant, well known, and uniformly distributed throughout the atmosphere. Thus, O_2 is an ideal candidate for reference measurements. The *O_2 A-band* wavelengths provide the required absorption spectra. The *O_2 A-band* spectra is particularly useful because it also indicates the presence of clouds and optically thick aerosols that preclude full column measurements of CO_2.

The design and architecture of the OCO spacecraft bus is based on the successful Solar Radiation and Climate Experiment (SORCE) and Galaxy Explorer (GALEX) missions. The spacecraft structure is made of honeycomb panels that form a hexagonal shape. This structure houses the instrument and the spacecraft bus components. The total weight of the Observatory is about 1170 lb (530 kg). Panels with solar cells are attached and stowed such that the whole structure fits inside the small fairing of the Taurus launch vehicle. A metal ring, mounted to the bottom of the structure, attaches the Observatory to the launch vehicle and separates the two after launch.

The on-board computer, which is designed to fly in the harsh space environment, controls the spacecraft bus components. This computer hosts software, which receives commands from an Earth station through an *S-band* antenna and returns telemetry and science data back to Earth using a high data rate *X-band* transmitter—S-band and X-band refer to specific frequency ranges of microwave radiation used for transmitting data.



The diagram illustrates how OCO obtains an X_{CO_2} measurement within its 3km^2 *footprint*. Molecules in Earth's atmosphere, such as CO_2 absorb radiation at very specific wavelengths. This means that the light reaching the OCO spacecraft will display diminished amounts of energy at these same wavelengths—i.e., the gases leave their *fingerprint* on the radiation as it passes through the atmosphere. The OCO spectrometers are designed to *detect* these *footprints*. They measure the intensity of reflected sunlight at these specific wavelengths and the level of absorption displayed reveals exactly how much CO_2 is present within the *footprint* area.

The spacecraft computer manages the pointing of the spacecraft. Ground commands tell the computer where to point the instrument. The computer uses four wheels to move the spacecraft. A star tracker verifies that the spacecraft has reached the correct orientation. In addition to pointing the instrument, the spacecraft must know where on Earth the footprint of the instrument is located. An on-board Global Positioning System (GPS) receiver provides that information.

Spacecraft software ensures that the solar arrays face the sun so that adequate power is always available to charge the battery and run all the components and the instrument. The power required to run the entire observatory is equivalent to the power needed for nine common household light bulbs.

Science Data Processing and X_{CO_2} Measurement

The principal science objective of the OCO mission is to gather global CO_2 data to help distinguish sources and sinks. **The OCO mission will not, however, *directly* measure CO_2 sources and sinks**. Computer based data assimilation models that use column averaged dry air CO_2 mole fraction (X_{CO_2}) data will infer the location of these sources and sinks.

To get the representative values of X_{CO_2}, the OCO instrument measures the intensity of reflected sunlight off of the Earth's surface at specific wavelengths. Gas molecules such as CO_2 in the atmosphere absorb radiation at specific wavelengths. So when the light passes through the Earth's atmosphere, the gases leave a distinguishing "fingerprint" on the residual radiation. The OCO spectrometers detect these molecular "fingerprints." The level of absorption displayed in these spectra will tell the number of molecules in the region where the measurement was taken.

The presence of clouds and optically thick aerosols such as smoke can block part of the distance, and thus partly block the complete measurement. Other conditions such as large topographic variations (over mountainous areas) within individual soundings can introduce additional uncertainty in length of the light column, which also affect the X_{CO_2} measurements. To counter this, the OCO instrument acquires a large number of densely spaced samples. Each sample covers an area of about 3 km^2—called a *footprint*—when the instrument is viewing locations looking straight down—or *nadir*—along the spacecraft's ground track. The OCO instrument can gather 39,600 of these soundings on the sunlit side of any orbit. With measurement footprints of this size and density, the OCO instrument can get a lot of high quality soundings even in regions where clouds, aerosols, and topographic variations are present.

Mission Operations

OCO will be launched from Vandenberg Air Force Base on a dedicated Orbital Sciences *Taurus XL (3110)* launch vehicle. It will initially be placed into a 398 mi (640 km) altitude, near-polar, dayside-ascending (i.e., moving south to north) orbit. The onboard propulsion system will be used to transfer the Observatory into its operational 438 mi (705 km) circular orbit. This orbit transfer and other in-orbit checkout activities are

expected to take less than 45 days. Once in its operational orbit, OCO will fly in the Earth Observing System (EOS) Afternoon Constellation (A-Train). The OCO orbit will be maintained with respect to Worldwide Reference System-2 (WRS-2), with a 1:27 p.m. ascending equator crossing time such that it will share its ground track with Aqua. This orbit facilitates direct comparisons and combined analyses of OCO observations with measurements taken by Aqua, Aura, CloudSat, Cloud-Aersol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), and other A-Train satellites. The orbit's 16-day ground repeat cycle facilitates monitoring X_{CO_2} variations over the entire sunlit hemisphere on semi-monthly intervals. The orbit period is 98.8 minutes, yielding 14.57 orbits/day or 233 orbits every 16 days. While sequential ground tracks are separated by ~24° of longitude, the spacing between adjacent ground tracks for the 233 orbits obtained over a 16-day ground repeat cycle is only ~1.5° of longitude.

OCO will switch from *Nadir* to *Glint* observations on alternate 16-day global ground-track repeat cycles so that the entire Earth is mapped in each mode every 32 days. Comparisons between *Nadir* and *Glint* observations will provide opportunities to identify and correct for biases introduced by the viewing geometry. *Target* observation will be acquired over an OCO validation site roughly once each day.

The same data sampling rate is used for *Nadir*, *Glint*, and *Target* observations. While the instrument is capable of collecting up to 8 adjacent, spatially resolved samples every 0.333 seconds (24 samples per second), the nominal data transmission and ground processing approach has been sized to accommodate only 12 samples per second as a cost saving measure. At this data collection rate, the Observatory collects ~200 soundings per degree of latitude as it travels from pole to pole, or ~7 million soundings over the sunlit hemisphere every 16 day ground repeat cycle. Therefore, the data collection rate can be at 12 samples/seconds at any time during the mission. Clouds, aerosols, and other factors will reduce the number of soundings available for X_{CO_2} retrievals, but existing studies suggest that at least 10% of these data will be sufficiently cloud free to yield X_{CO_2} estimates with accuracies of ~0.3 to 0.5% (1 to 2 ppm) on regional scales at monthly intervals.

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feature articles

A Brazilian Wind: Measuring Energy Potential

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

Developers need solid assessments of coastal wind energy potential before they can consider a new wind project, and that information can be hard to get using traditional ground-based tools.

With the average price of a gallon of gasoline hovering somewhere around $4 in the U.S. and oil prices continuing to rise, our nation and our world are refocusing their attention on the viability of alternative energy sources. A window seems to be opening for genuine progress in lessening our dependence on fossil fuels. One source of energy that has been proposed and used effectively on a limited scale is wind power. In light of this, ***The Earth Observer*** *reprints this article that was prepared for the 2008 edition of* ***Sensing Our Planet: NASA Earth Science Research Features****, which will be in print sometime in late 2008. The article reports on interesting research to try and expand the use of wind power in Brazil and how NASA satellite data has aided the effort.*

People often picture wind turbines rooted in waving fields of golden grass in rural landscapes, but wind turbines can also stand in the waves of coastal waters. Offshore wind energy is more than just clean and economical; like land-based wind energy, winds over the ocean can often be faster and fluctuate less, leading to higher and more sustained output. Offshore wind sites tend to be naturally close to the large coastal population centers that need their power, and they do not have to compete with real estate for valuable land. Plus, offshore wind technology is a proven renewable energy source. **Willette Kempton**, a professor at the University of Delaware, said, "Offshore wind power is particularly attractive because the resource is large and current technology is ready for implementation now."

So if wind energy is poised to provide the world with clean power, why are turbines not up and spinning along every coastline? Developers need solid assessments of coastal wind energy potential before they can consider a new wind project, and that information can be hard to get using traditional ground-based tools. In an effort to help assess wind energy potential, Kempton and his colleagues are using an unexpected tool—satellite data. Their latest project focuses on the undulating coastline of Brazil.

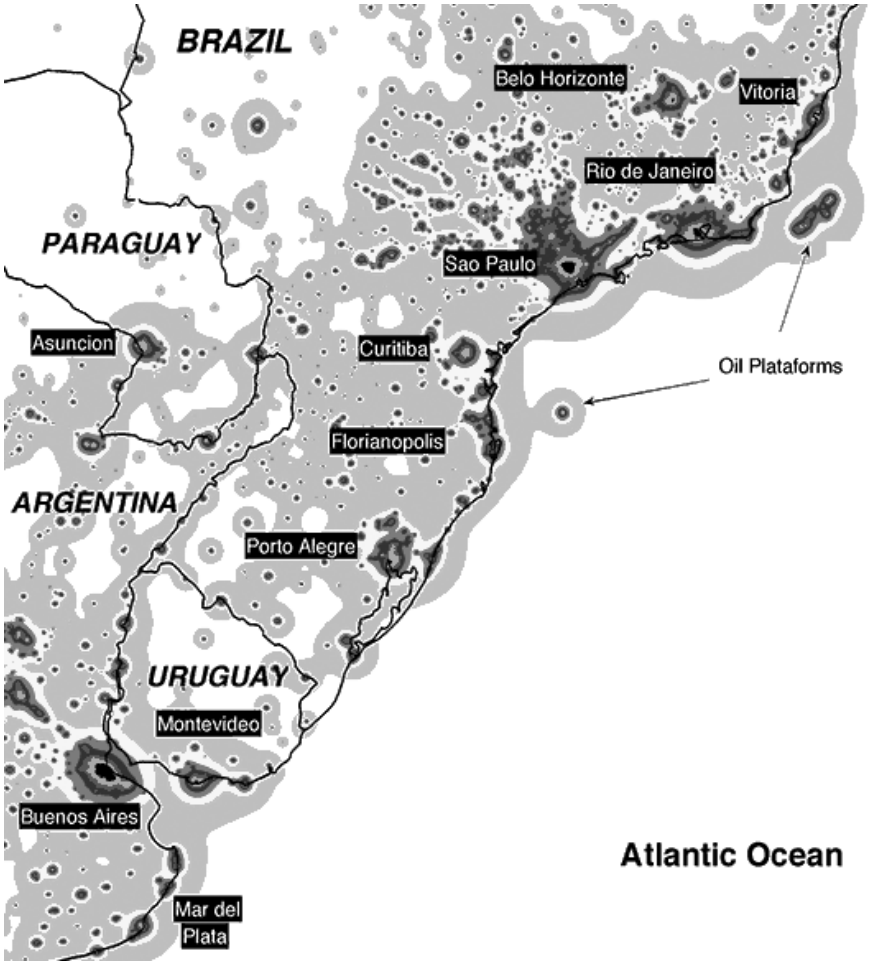
Location, Location, Location

Whether along the coast of northern Europe, the United States, or Brazil, to produce cost-effective electricity, wind turbines need to be sited in an area with a few specific requirements.

First, wind speeds must fall within a defined zone. Kempton said, "The ideal wind-speed zone has winds that are high enough to produce energy but without strong

Offshore wind turbines take advantage of predictable winds, are often close to electricity-hungry population centers, and provide carbon-free energy using proven technology. **Image credit:** phault.

storms that pose a threat to the installation." Second, offshore turbine foundations must be on relatively shallow coastal shelves; the deepest installed turbine is currently rated for 164 ft (50 m) in depth. Finally, the site must be able to accommodate the whirling blades of enough turbines to be cost-effective. Kempton said, "The idea is to fan them out and make sure they are spaced apart appropriately for effective energy production."



The offshore study area bounds 560 mi (900 km) of Brazil's coastline, shown in this nighttime image. Dense population centers are labelled; the two onsite sources of wind speed data within the study area are labeled as oil platforms. To view this image in color go to: *nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html*. **Image credit:** Elsevier courtesy Felipe Pimenta.

The wind industry and turbine manufacturers are concerned with all of these details; scientists are, too. "Coastal zone assessment is the piece that scientists, like our team, can provide," Kempton said. "Think of it like petroleum or coal: you need a resource assessment so that you have a sense of how much resource is located where, and how you'll need to extract it. That's what we need to do with offshore wind."

One of the most recent and promising wind assessment studies that Kempton and his University of Delaware colleagues **Richard Garvine** and **Felipe Pimenta** developed was to determine wind energy potential off the coast of southeastern Brazil. Pimenta, a native of Brazil, said, "My goal is to search for renewable energy solutions that can help diversify the Brazilian electric grid."

Assessing a Brazilian Wind

At present, most of Brazil's electricity comes from hydroelectric dams, with a sizable portion from traditional fossil-based resources and only a small percent coming from renewable resources like wind. Now, Brazil seeks to increase its share of renewable energy. Pimenta said, "A new government program, *ProInfra*, seeks to increase the use of new renewables to 10% of our annual electricity consumption. Our study is important because it is the first to evaluate Brazil's offshore wind potential."

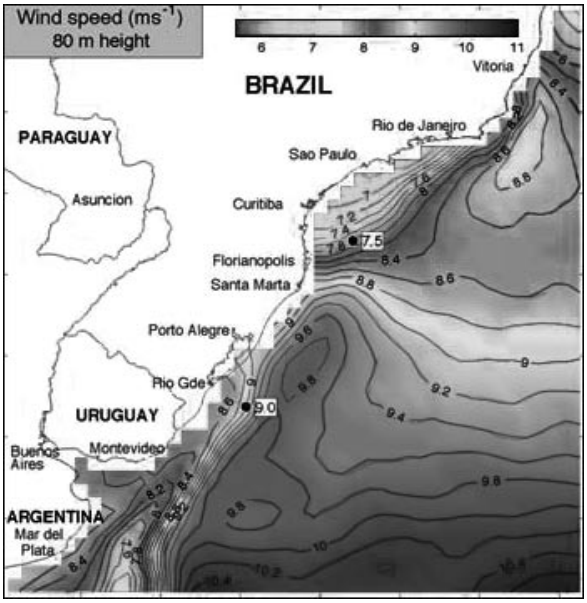
With its bustling, coast-hugging population centers like São Paulo and Rio de Janeiro, offshore wind is a promising fit for Brazil. "Brazil has a long coastline and vast continental shelves and it seems to have even more wind resources than we might have expected," Pimenta said.

With its bustling, coast-hugging population centers like São Paulo and Rio de Janeiro, offshore wind is a promising fit for Brazil. "Brazil has a long coastline and vast continental shelves and it seems to have even more wind resources than we might have expected," Pimenta said.

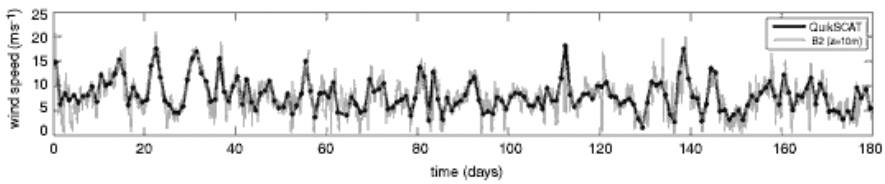
Typically, wind energy assessments begin by analyzing data from continuously operating meteorological stations or buoys that float offshore near the potential site. These stations measure wind speed up to 66 ft (20 m) above the sea surface. From these measurements, scientists extrapolate the wind speed at the turbine's hub height, approximately 262 ft (80 m), to get an idea of the wind available to turn a turbine's blades. Researchers also use station data to analyze wind-speed fluctuations from one minute to the next. However, meteorological data from buoys and fixed platforms can be hard to get. Kempton said, "Many countries simply lack historical meteorological buoy information over the ocean." The chosen study area turned out to be a good example of the sparseness of meteorological station data. Kempton said, "For the entire study area, we only had two offshore buoys available."

Given the lack of wind speed data from meteorological stations, the team needed a different source. "In a new offshore wind power seminar we teach at the University of Delaware, student **Oleksiy Kalynychenko** suggested using NASA Quick Scatterometer (QuikSCAT) data—and Felipe decided to try it. To our knowledge, this study is the first to use QuikSCAT to assess wind power resources over a large ocean area," Kempton said. The SeaWinds instrument, on board the QuickSCAT satellite, provides scatterometer data that is hosted by the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC). The instrument measures ocean roughness and relates it to wind speed at the ocean surface. "QuikSCAT has exceptional global geographic coverage at a very reasonable spatial resolution—from just over 8–31 mi (12–50 km)," Kempton said. "The satellite data filled in the gaps in the vast areas around the two buoys."

Before settling on QuikSCAT, the scientists first wanted to confirm that the satellite data correlated well to existing buoy data. "We crosschecked meteorological data from several places against QuikSCAT to ensure that we could use the satellite data for assessing the Brazilian power resource," said Kempton. By combining the meteorological and QuikSCAT data, the team could also address a limitation of the satellite data. Wind speeds can fluctuate from minute to minute and from hour to hour, so unless data is taken continuously—as meteorological stations are able to do—those fluctuations will not be captured. Kempton said, "When the satellite passes over the study region, that's when you get the data—once or maybe twice per day. The buoys are running continuously, but in only a few places. The two together provide both spatial and temporal coverage." One of the two buoys within the study area was particularly helpful for this purpose because it took measurements during the same months that QuikSCAT passed overhead. "We could confirm that the satellite data was within acceptable margins of error for a first-cut evaluation of power resources," he said. "QuikSCAT can



Wind speeds at a height of 262 ft (80 m)—approximately the hub height of a turbine—show a viable wind resource in the study area. If the area were to become a fully developed offshore wind project, it could supply more than the country's current electricity needs. To view this image in color go to: *nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html*. **Image credit:** Elsevier courtesy Felipe Pimenta.



QuikSCAT satellite wind speed data correlated well with wind speed data taken from an onsite meteorological station. In this sample data, the thick black line shows QuikSCAT and the thin gray line shows the station data. To view this image in color go to: *nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html*. **Credit:** Elsevier courtesy Felipe Pimenta.

indeed provide practical measures of wind power, especially when looking for monthly or yearly estimates."

Where the Wind Blows

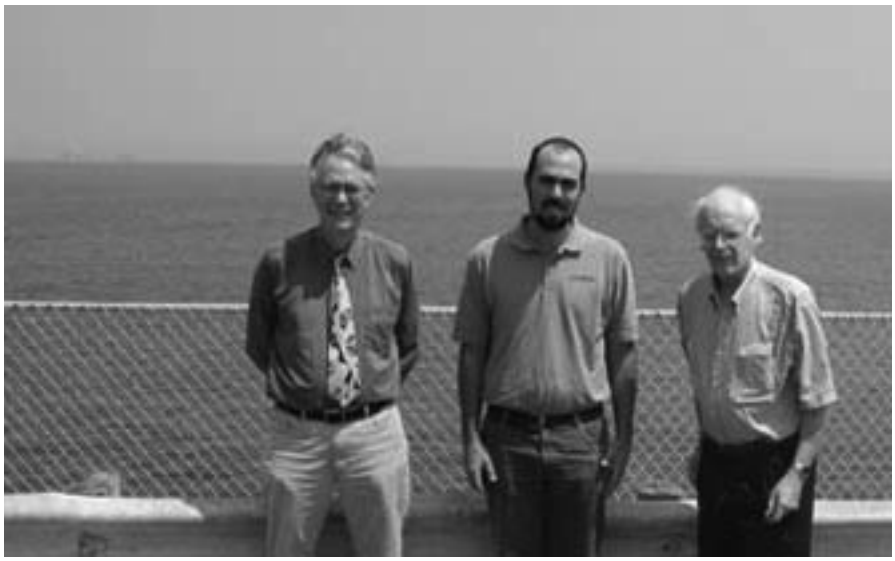
Having cross-referenced the buoy and satellite data, the scientists' next step was to explore the "footing" on which turbines could stand in the study area. "Felipe got bathymetric information by digitizing Brazilian Navy nautical charts," Kempton said. "This helped us estimate the shelf areas that are within the practical limits of exploration, in terms of depth."

Kempton and his team now had the information they needed to assess the practical wind-turbine-worthy wind resource: the wind speed at hub height over a large area from the satellite data; an idea of the fluctuations of wind speed based on the hour and season from both buoy and satellite data; and the depth of the continental shelf, where the turbines would be planted, from the bathymetric data.

Using all of this information, Kempton, Garvine, and Pimenta calculated the potential power production for two different wind turbine models. Kempton said, "The total average electricity use of Brazil is near 100 gigawatts, and the offshore wind resource of this one section of coast, to only 164 ft (50 m) of water, is 102 gigawatts." **That means that if the study area were to become a fully built wind energy project, it could supply enough electricity for the entire country's electricity needs.**

"However," Kempton said, "there would certainly be areas that would be excluded from development, and we didn't attempt to consider those in our calculation. According to previous studies, exclusions for shipping lanes, marine conservation sites, and commercial fishing, could reduce the site's capacity by 10–46%." Even with areas

That means that if the study area were to become a fully built wind energy project, it could supply enough electricity for the entire country's electricity needs. … Even with areas excluded from development, an offshore wind project in the study region could still meet ProInfra's efforts to increase Brazil's renewable energy output.



Scientists Willett Kempton, Felipe Pimenta, and Richard Garvine worked together on the research featured in this article. Richard Garvine was widely considered a pioneer and international authority in the field of coastal physical oceanography; more recently, he was dedicated to the study of renewable energy solutions. He served as close mentor to Felipe Pimenta, as well as many other young oceanographers, during his thirty-eight-year career. Garvine passed away last fall. **Photo credit:** Felipe Pimenta.

... 'Wow, this makes me very optimistic. I thought climate change was all doom and gloom. But we can actually do something to turn it around.' And, given the technologies already available today, offshore wind is one of the best options out there."

excluded from development, an offshore wind project in the study region could still meet *ProInfra's* efforts to increase Brazil's renewable energy output.

Kempton feels optimistic about the future of the team's work, but he also recognizes some challenges. He said, "The work on the Brazilian wind assessment was the first step in a larger picture. We hope to make a database of wind assessments available for various coastal areas—wind resource, energy demand, potential electrical output and revenue, et cetera. We think this would help the wind industry decide whether or not a site is feasible economically and help with government planning."

Pimenta agreed, adding, "I want to return to Brazil and continue this work. There are still many tools, including satellite data, left for us to explore as we look at wind energy. I hope our work will help other large countries estimate their wind resources, too." A better understanding of global offshore wind potential could help many countries reduce their portion of humanity's carbon output.

The main message, from Kempton's perspective, is one of hope. "In the end," he said, "people really understand the results of this type of research. They say things like, 'Wow, this makes me very optimistic. I thought climate change was all doom and gloom. But we can actually do something to turn it around.' And, given the technologies already available today, offshore wind is one of the best options out there."

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Pimenta F., W. Kempton, and R. Garvine. 2008. Combining meteorological stations and satellite data to evaluate the offshore wind power resource of Southeastern Brazil. *Renewable Energy,* doi:10.1016/j.renene.2008.01.012.

Related Links

- Centre ERS d'Archivage et de Traitement, French ERS Processing and Archiving Facility (CERSAT) *www.ifremer.fr/cersat/en/welcome.htm*
- NASA Physical Oceanography DAAC *podaac.jpl.nasa.gov/*
- NASA QuikSCAT satellite *winds.jpl.nasa.gov/missions/quikscat/index.cfm*
- Willett Kempton, University of Delaware, College of Marine and Earth Studies *www.ocean.udel.edu/people/profile.aspx?willett*

Research & Discover Interns and Fellows Present Results

Alan B. Ward, NASA Earth Observing System Project Science Office, award@sesda2.com

The *Research & Discover* (R&D) Program is a joint collaboration between NASA Goddard Space Flight Center (GSFC) and the University of New Hampshire (UNH). R&D connects upper level undergraduate and graduate students in Earth science disciplines with some of the nation's top scientists at UNH and GSFC to participate in important scientific research projects going on at both institutions.

The undergraduate students take part in a 10-week summer internship at UNH and can apply for a second internship at GSFC. (Following the second internship, the students are eligible to apply for a graduate fellowship at UNH as described below.) While at UNH and/or GSFC, the students get to experience what it is like to conduct advanced university research in Earth, ocean and atmospheric sciences. The students also receive a stipend and room and board during their internship(s).

Meanwhile, the graduate students who are selected to take part in R&D participate in 2-year graduate fellowships through the UNH-Goddard Joint Center for the Earth Sciences. The students enroll in a graduate program at UNH and are involved in research conducted jointly at UNH and GSFC.

"Some people can only dream of an opportunity to participate in a scientific adventure that could provide the know-how to be competent and comfortable in a science-related area. I took a scientific journey this summer at The University of New Hampshire through the Research and Discover Program." — **Jerome Mitchell** [Elizabeth City State University—*R&D Intern, 2006-07*]

"Research and Discover has allowed me to utilize the strong ties between NASA and UNH. As a graduate student, the chance to travel not only to Goddard Space Flight Center, but also to conferences and research sites around the U.S. is extremely valuable. My R&D fellowship enables me to connect both with my peers and with distinguished scientists." —**Amanda Plagge** [Dartmouth College—*R&D Fellow, 2006-08*]

Right from the start, the students work in tight collaborations with researchers who are recognized as leaders in the national and international scientific community. The geoscience and environmental science research results produced from projects these students take part in are among the most frequently cited in the country. R&D students work with the program to select a research topic that closely matches their own interests.

For more information please visit: *www.eos.unh.edu/ResearchAndDiscover/index.shtml.*

Students participate in research on areas such as:

- investigating climate change and the effects of human activities on the Earth;
- analyzing samples of snow, ice, and the atmosphere to study climate change;
- exploring chemical, physical, and biological oceanography; and
- studying dynamic processes in the Earth, oceans, and atmosphere using remote sensing, GIS, computer models, and other state-of-the-art tools.

On August 6, many of the students who participated in the R&D Program as interns and fellows gave short presentations on the research that they did at Goddard this summer. *The Earth Observer* presents the following summary of their presentation session.

George Hurtt [UNH—*Institute for the Study of Earth, Oceans, and Space (Director of R&D)*] welcomed everyone to the presentations. R&D is designed to help recruit and train students and help them get established in Earth science research careers. Hurtt also emphasized the continued growth and productivity of the R&D program.

Franco Einaudi [NASA GSFC—*Director of the Earth Sciences Division of the Sciences and Exploration Directorate*] shared some closing remarks. Einaudi is an advocate for programs like R&D that promote partnerships between government agencies and academia. He himself spent 10 years of his career working for the National Oceanic and Atmospheric Administration (NOAA) and the Cooperative Institute for Research in Environmental Sciences of the University of Colorado in Boulder, CO, a joint NOAA–University of Colorado program. Einaudi took a moment to thank all the students for the hard work they have done and he especially wanted to thank the parents that had come to support the students. He also encouraged the students to keep Goddard in mind down the road when it comes time to consider a career. Goddard very much needs the "best and brightest" young scientists to come to work there as it moves toward the future.

Olivia DeMeo [Illinois Wesleyan University—*2008-09 Intern*]; **Advisor**: Joseph Salisbury [UNH]

De Meo presented *The Effect of River Alkalinity on Coastal Aragonite Saturation*. Her study addressed the regional variability of total alkalinity (TA) in rivers and its effect on the aragonite saturation state (Ω) at river mouths. The TA concentration of river water is its ability to buffer changes in pH. Ω is an index that expresses the availability of calcium and carbonate ions, which calcifying organisms use to make their shells. Local river sampling in New England, U.S. and New Brunswick, Canada showed regional differences in TA concentrations, which are likely related to bedrock and land use patterns. U.S. Geological Survey alkalinity data for rivers entering the East and Gulf Coasts, showed a regional pattern of low TA in northern rivers and higher TA in the southern and Gulf rivers. Estimated aragonite saturation states revealed that most rivers were under-saturated, and only a few rivers (mainly entering the Gulf) were super-saturated. This widespread under-saturation near the coast may have detrimental effects for calcifying organisms that rely on aragonite to build their shells.

Michael Hutson [Stanford University—*2008-09 Intern*]; **Advisor**: George Hurtt [UNH]

Hutson's presentation was entitled *Giants in the Hills: Fieldwork and Forest Modeling at the Sierra Study Area in Preparation for the DESDYNI Satellite Mission*. He touched on the importance of understanding the terrestrial carbon cycle and the search for missing carbon sources. He mentioned aircraft [Laser Vegetation Imaging Sensor (LVIS)] and satellite [Ice, Clouds, and Land Elevation Satellite (ICESat)—present; Deformation, Ecosystem Structure and Dynamics of Ice (DESDYNI)—future] lidar measurements of canopy height. He discussed the Ecosystem Demographics (ED) global ecosystem model and his final research at the Sierra study site. Hutson showed results comparing ED to both LVIS observations and preliminary field observations, and suggested next steps for his research.

Genevieve Noyce [Mt. Holyoke College—*2008-09 Intern*]; **Advisor**: Ruth Varner [UNH]

Noyce spoke about *The Role of Sedges in Methane Production and Emission from a Temperate Fen*. Fens are a type of *peatland* (waterlogged ecosystem), and are important sources of atmospheric methane (CH_4). She discussed how methane is produced belowground and transported into the atmosphere and the effect *sedges* (grass-like plants) have on these processes. Noyce wanted to determine why CH_4 fluxes are higher in the presence of sedges. She did fieldwork in Sallie's Fen in Barrington, NH, including an experiment in which she removed sedges from several plots. Preliminary results show that higher CH_4 fluxes seem to correlate well with higher sedge biomass and more CH_4 is trapped underground when the sedges are removed. Noyce also showed a map of global CH_4 from Aqua/AIRS to illustrate that her local research has global connections.

Claire Plagge [St. Lawrence University—*2008-09 Intern*]; **Advisor**: Steve Frolking [UNH]

Plagge's presentation focused on *Slash and Burn Agriculture: Incorporating Shifting Cultivation into a Global Land Use Model for Earth System Model Applications*. She explained what *shifting cultivation* is and why it is important for modeling studies. Plagge reviewed 36 case studies of shifting cultivation in the course of her research but decided to focus on two large studies; she shared key findings from the various studies. Plagge then described the work she is doing to create a new model to determine shifting cultivation from 1970–2000. She ended by discussing future enhancements that might be made to extend the model's applicability and also discussed connections to remote sensing—i.e., possible use with the proposed DESDYNI mission.

Matthew Wiener [Vasser College—*2008-09 Intern*]; **Advisor**: Barry Rock [UNH]

Wiener detailed his research toward *Development of a Hyperspectral Index for Detection of Initial Water Stress in Eastern Hemlock (Tsuga canadensis)*. He started with some biological background on his research. Hemlock is something of an "ecosystem engineer" because it creates a dark environment that can sustain other species. Hemlock woolly adelgid (HWA) is an invasive species introduced in the 1950s that is particularly destructive to hemlock. Wiener wants to understand why HWA is so destructive to hemlock. He speculated that it might be related *water stress* since hemlock is extremely sensitive to drought as well as other possible reasons. Wiener conducted fieldwork in New Hampshire to test his hypothesis and his results show that hemlock does have a clear spectral response to changing water levels. He created two spectral indices for looking at the correlation with initial water loss and discussed some possible future applications of his work.

Emily Glick [Bryn Mawr College—*2007-08 Intern*]; **Advisors**: Jamie Pringle [UNH], Donald Cavalieri [GSFC]

Glick presented results from an *Assessment of EOS Aqua AMSR-E Sea Ice Concentrations Using MODIS*. She started with background on *sea ice* and why it is important to study. Glick combined Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) data on Antarctic sea ice for her analysis and explained her process for data analysis to separate clouds and sea ice in MODIS images. Large errors in the analysis could be from unresolved weather, cloud cover, and flooded ice. Many more images and data analysis will be needed to completely validate AMSR-E data in the future.

Jordan Goodrich [UNH—*2007-08 Intern*]; **Advisors**: Ruth Varner [UNH], J. Rodriquez [GSFC]

Goodrich's presentation was aimed at *Assessing the Uncertainty in the Global Distribution of Atmospheric CH_4 using Aqua/AIRS and GMI CTM*. He began with some background describing the current issues surrounding atmospheric methane (CH_4), particularly the recent slow-down in the global growth rate. Goodrich discussed some of the uncertainties in constraining the global budget of sources and sinks in order to justify the need for improved measurements and global models. The question he addressed was whether comparisons between new satellite products for CH_4 and atmospheric chemistry and transport model output can yield information on areas needing the most improvement in both. There are differences between model results [from the Global Modeling Initiative (GMI)] and satellite measurements [from the Atmospheric Infrared Sounder (AIRS) on Aqua] that may be linked to intense cloud cover in the tropical regions as well as surface albedo properties of the ocean. Solar zenith angle, and snow and ice cover may also play a role in reflectance problems in the northern high latitudes during winter months as the surface becomes extremely bright and the cloud cover is low, particularly in Siberia and over the Hudson Bay. Goodrich's summer project was successful in identifying some major issues in both the satellite retrieval and the model output and his next step will be to quantify these issues in order to correct the final data product. Goodrich also plans some step-by-step improvements for the CH_4 emission inputs to the model as more accurate data become available for both the magnitude and distribution of global CH_4 sources.

Andrew Maher [UNH—*2007-08 Intern*]; **Advisors**: Rob Braswell [UNH], Elizabeth Middleton [GSFC]

Maher presented details on *An Examination of the Relation between Burn Severity and Forest Height Change in the Taylor Complex Fire using LIDAR data from ICESat/GLAS*. He began by discussing his motivation for the study and describing how burn severity is calculated using data from the Landsat Thematic Mapper. The GLAS lidar on ICESat has a 70-m diameter *footprint* spaced every 175 m and can be used to get a distribution of the canopy height within the footprint. Maher's hope was to use GLAS data to look at burn severity and forest height change caused by the Taylor Complex fire in 2004.

Haley Wicklein [Earlham College—*2007-08 Intern*]; **Advisors**: Scott Ollinger [UNH], James Collatz and Jeff Masek [GSFC]

Wicklein presented an *Analysis of Forest Fire Disturbance in the Western U.S. Using Landsat Time Series Images: 1985-2005*. She explained that forests are important carbon sinks but are not well quantified. Wicklein used two different disturbance maps for her study—North American Forest Dynamics Project (NAFD) and Monitoring Trends in Burn Severity (MTBS)—to assess disturbance trends in Western US forests. She looked at four Landsat time series cubes in Oregon, California, Idaho, and Utah. She looked at the Normalized Burn Ratio (NBR) and the Normalized Difference Vegetation Index (NDVI) and tried to determine if these indices provide useful ecological information about forest recovery after disturbance. Wicklein's findings suggest that only 7–30% of total disturbance is attributed to fire—lower than we might expect—and also that, although NDVI and NBR can give useful information on timing and magnitude of disturbance, they do not provide information about long-term forest regeneration.

Jennifer Wurtzel [University of Michigan—*2007-08 Intern*]; **Advisors**: Cameron Wake [UNH], Josefino Comiso [GSFC]

Wurtzel discussed *The Arctic Oscillation and its Influence on Sea Ice and Polar Precipitation*. She began by showing the Sea Ice Anomaly of 2007 and giving some background on the Arctic Oscillation (AO) and the related North Atlantic Oscillation. Wurtzel explained that changes in AO impact other variables such as precipitation in Greenland and Scandinavia and sea ice extent in the Baffin Bay and Barents Sea. She further suggested that the AO pattern may be becoming *neutral* over the past decade and this may mean that changes in precipitation and sea ice are attributed to other factors such as global warming.

Kathryn Berger [UNH—*2006-08 Fellow*]; **Advisors**: Scott Ollinger [UNH], Elizabeth Middleton [GSFC]

Berger presented an *Evaluation and Improvement of Model Algorithms for Predicting Belowground Carbon Allocation in Forest*. She gave some background on Total Belowground Carbon Allocation (TBCA) and why it is important but difficult to measure and model. Berger worked with the Photosynthetic/EvapoTranspiration-Carbon/Nitrogen (PnET-CN) model and explained how it works. She wanted to see how well the model worked at predicting TBCA. She used field measurements at Free-air Carbon Dioxide Enrichment (FACE) sites at Aspen in Colorado, Duke University in North Carolina, and Oak Ridge National Laboratory (ORNL) in Tennessee, and found that observations didn't match with what the model predicted. Berger thus attempted to create a modified TBCA mechanism in the model that would produce results more consistent with observed results. She shared results using the modified TBCA mechanism and told how the new mechanism might change previous estimates of TBCA, forest productivity, and carbon storage done with the old model.

Katelyn Dolan [UNH—*2007-09 Fellow*]; **Advisors**: George Hurtt [UNH]; Jeffrey Masek and James Collatz [GSFC]

Dolan's research was aimed at *Evaluating Large-Scale Forest Disturbance Resulting from Hurricane Katrina using Geoscience Laser Altimeter System (GLAS) Lidar*. She explained the relevance of her study—hurricanes are thought to be a major factor in reducing long-term carbon storage—and gave some specific background on Hurricane Katrina. Most studies to date have used optical remote sensing or limited field measurements. Dolan would like to add a direct structural measurement using lidar data—i.e., can the GLAS lidar be used to detect and help quantify forest disturbance caused by Katrina? (She pointed out that GLAS did not have vegetation studies as its primary objective so it is not perfect for these observations.) Dolan explained the challenges of trying to go from a waveform to forest structure and the procedure she used to do her study. She showed some preliminary results—a definite shift toward shorter canopy heights for Category 1 and 2 windspeeds over the areas impacted by Katrina for all seasons, but not nearly as clear for lower wind speeds. The next steps for her research include using the Ecosystem Demographics (ED) global ecosystem model to predict how much the biomass loss caused by Katrina would reduce carbon storage.

Erica Lindgren [UNH—*2007-09 Fellow*]; **Advisors**: Barry Rock [UNH], Elizabeth Middleton [GSFC]

Lindgren's talk was called *Anthocyanins as Antioxidants in Trees: Finding a Way Towards the Truth*; she described research aimed at creating a spectral index for anthocyanins. *Anthocyanin* is a red pigment found in many plant species and can be seen notably in New England during the autumn. She explained that anthocyanin is thought to be a universal indicator of plant stress—therefore detecting its presence would be useful for ecosystem analysis and for monitoring changes during autumn senescence. Determining an anthocyanin index that can be used with satellite systems will provide greater understanding of plant stress distribution and senescence over large areas. With their wide variety of anthocyanin concentrations, focusing on sugar maple stands in the fall will allow Lindgren to optimize the likelihood of detecting anthocyanin and allow calibration of a spectral index against field observations. Since the spectral resolution of satellite systems varies, she plans to compare the proposed anthocyanin to spectral bands available from various systems to see which most accurately represents changes in anthocyanin concentration. If detecting anthocyanin concentrations can be accomplished through satellites, then one can monitor fall foliage or general plant stress. Tracking the health of sugar maple trees would be a useful diagnostic tool as their habitat is projected to disappear in the U.S. by 2100 according to current climate models used by the Forest Service-Forest Inventory Analysis (FIA). Lindgren is also interested in what role anthocyanins play in senescing leaves and will be tracking the antioxidant capacity of leaves in connection with anthocyanin concentrations.

Virginia Sawyer [Cornell University—*2007-09 Fellow*]; **Advisors**: Ruth Varner [UNH] Judd Welton and Timothy Berkoff [GSFC]

Sawyer discussed *Preliminary Micro-pulse Lidar Observations During ICEALOT, March-April 2008*. This research involved using a ground-based lidar to measure aerosol. Sawyer gave some background on the importance of aerosols to climate change—especially in the polar regions. She also gave some background on Arctic haze and on the Micro-pulse Lidar (MPL). Sawyer showed some MPL results from the International Chemistry Experiment in the Arctic Lower Troposphere (ICEALOT), a NOAA-funded research cruise that studied the Arctic haze. She used back Hybrid Single-Particle Lagrangian Integrated Trajectories (HYSPLIT) to find the origin of one haze event. MODIS photographs and FLEXPART Lagrangian particle dispersion model chemical forecasts added evidence that the source of the aerosol was a series of fires in southern Russia—4800 km away! In the future, Sawyer would like to compare data from MPL with data from the Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite.

Mimi Szeto [Wellesley College—*2007-09 Fellow*]; **Advisors**: Janet Campbell [UNH], Charles McClain [GSFC]

Szeto's research focused on *Evaluating Two Approaches to the Bio-Optical Model for Coastal Waters*. Her research is part of a larger effort to estimate ocean primary productivity. Szeto gave background on her research including discussion of the important role of ocean biology in the global carbon cycle. For her thesis, she will examine two different models used in ocean color algorithms that develop chlorophyll measurements. The models relate *apparent optical properties* (i.e, reflectance measured from a satellite or radiometer) to *inherent optical properties* (i.e., absorption and scattering properties of the water). She described how this relationship drives bio-optical models and algorithms. Szeto will use *in situ* data from the Gulf of Maine; Monterey Bay, CA; and Bermuda and will also simulate data using a radiative transfer model called Hydrolight. ■

Landsat Science Team Meeting Summary

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Meeting Overview

The U.S. Geological Survey (USGS)–NASA-sponsored Landsat Science Team met for the fourth time on July 15–17, 2008, at the USGS National Center in Reston, VA.

The objectives of this meeting were to:

- assess the operational status and activities associated with Landsats 5 and 7;
- discuss Landsat Data Continuity Mission (LDCM) implementation progress; and
- review the science and applications activities of the Landsat Science Team principal investigators.

A particularly important element of the meeting included presentations and discussions on uncertainties in both LDCM and the proposed National Land Imaging Program (NLIP). All presentations used during the meeting are available at: *landsat.usgs.gov/science_july2008MeetingAgenda.php.*

Bruce Quirk [USGS—*Land Remote Sensing Program Coordinator*] opened the meeting and thanked the Landsat Science Team for supporting efforts to make the Landsat archive available for no-cost Internet access.

Barbara Ryan [USGS—*Associate Director for Geography*] also expressed her appreciation for the team's contributions on a number of Landsat issues, and especially for the May 28, 2008, editorial in *Science* on *web-enabled* free Landsat data. She also emphasized the challenges ahead to make Landsat an operational program.

Curtis Woodcock [Boston University—*Landsat Science Team Leader*] with Landsat Science Team co-chairs **Tom Loveland** [USGS] and **Jim Irons** [NASA Goddard Space Flight Center (GSFC)] reviewed the accomplishments from the first three meetings that addressed requirements for thermal infrared imaging, the necessity for no-cost access to the Landsat archive, as well as the consolidation of Landsat holdings in international archives into a single archive, and valuation of key LDCM requirements. Woodcock also emphasized the need to look beyond LDCM in order to ensure an operational Landsat future.

Landsat 5 and 7 Status and Activities

Kristi Kline [USGS—*Landsat Project Manager*] gave an overview of the status and health of Landsats 5 and 7. Landsat 5, launched in 1984, continues operational acquisitions. A battery anomaly that occurred in October 2007 caused a suspension of operational imaging until March 2008. However, the team implemented a new power configuration and operations strategy, and Landsat 5 was able to resume imaging over areas of the globe serviced by ground stations. Landsat 7 continues to collect global data despite the Scan Line Corrector anomaly. Recent solid state recorder problems have reduced storage capacity by approximately 20%, but the problems have not had any additional impacts on the Landsat 7 Long Term Acquisition Plan (LTAP). The team is working on recovery procedures and will attempt to restore additional storage capacity. With both Landsats 5 and 7 past their design life, there is an increasing chance of mission-ending failures. However, both satellites have sufficient onboard fuel to continue operating for several years. Barring catastrophic system failure, the USGS has a goal to operate both satellites through 2012.

Kline also gave a report on the status of USGS efforts to *web-enable* the complete Landsat archive. In April 2008, the USGS announced plans to make all Landsat data—both new acquisitions and data in the archive—available electronically over the Internet to users at no charge. The original intent was to make all data available by February 2009 but an accelerated schedule now targets a late December 2008 release of all data from Landsats 1-7. All new global Landsat 7 acquisitions were released in July 2008, and all archived Landsat 7 data will be available in September 2008. The remaining Thematic Mapper (TM) Multispectral Scanner (MSS) data will be released in December. Once the Landsat archive can be fully accessed electronically all Landsat data purchasing options from the USGS will be discontinued.

Kline and **Loveland** led a discussion on criteria that could be used to assess when it is necessary to end the Landsat 5 and 7 missions. The actual mission end will be the result of substantial decline in data quality or quantity, failed mechanical or electronic subsystems, or fuel depletion. The Landsat Science Team considered the issues associated with declines in data quality and quantity and concluded that decision-making is *situational*, and thus it is difficult to establish specific criteria. Instead, they suggested that a monitoring strategy be followed that includes internal assessments of data quality as well as periodic reviews by outside experts. The team offered to review data on anomalous conditions. Factors that need to be monitored include correctable versus uncorrectable geometric and radiometric

variations, reductions in acquisition coverage and scene quantity, utility of degraded data for key applications, and access to alternate data sources.

Jeff Masek [NASA GSFC—*Deputy LDCM Project Scientist*] and **John Dwyer** [USGS—*LDCM Project Scientist*] provided an update on the Global Land Survey (GLS) 2005 initiative. GLS 2005 adds global, cloud-free, orthorectified Landsat data from 2005 to the GLS series that already includes 1975, 1990, and 2000 Landsat images. GLS 2005 is primarily based on Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 5 TM imagery, with Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Earth Observing-1 Advanced Land Imager (ALI) data used as needed. The Landsat 7 portion of GLS 2005 will be completed and available by the end of July 2008, and the Landsat 5 data will be completed by the end of September 2008; the entire database will be completed by the end of December 2008.

With GLS 2005 nearing completion, planning has begun on adding 2010 coverage to the GLS collection. Masek and Dwyer reported that NASA and the USGS are developing GLS 2010 as an international initiative with Landsat TM and ETM+ serving as the baseline with data from international space agencies included in the overall dataset. The Committee on Earth Observation Satellites (CEOS) Land Surface Imaging (LSI) Constellation Study Team (see details below) is being consulted about playing a role in formulating international participation. The planning team hopes to begin implementing GLS 2010 by early 2009 with global image acquisitions ongoing between 2009 and 2011.

Bryan Bailey [USGS—*Principal Scientist*] updated the team on the CEOS LSI Constellation study. The LSI study team is working toward international cooperation in mid-resolution (e.g., Landsat) scheduling, acquisitions, processing, and sharing so that there is more complete global coverage available for addressing societal issues. The GLS 2010 initiative, for example, has a goal of using data collected by the various members of the constellation. Bailey explained that the team is forming a Working Group on Regional Dataset Compilation that will select one or two regions (subcontinental or larger in size) for which mid-resolution data will be acquired and compiled by mid-resolution satellite systems operated by CEOS agencies. The next steps for acquiring new data that contribute to GLS 2010 will be specified based upon the results of the regional dataset compilation effort.

Steve Covington [The Aerospace Corporation—*Landsat 5 and 7 Flight Systems Manager*] provided a brief update on a USGS feasibility study for establishing a consolidated global Landsat archive. Over the past 35 years, over 50 ground stations have been configured to receive Landsat data, and 19 are currently active. Many of the Landsat scenes found in the international ground station archives are unique and not duplicated in the USGS archive at the Earth Resources Observation and Science (EROS) Center near Sioux Falls, SD. Almost 4.5 million scenes are estimated to be held in international archives compared to 2 million in the USGS EROS archive. There is growing concern about the state of historical archives, especially at inactive stations where there are no operational contacts. A consolidated archive would better support/facilitate global change analysis and assessment. Initial discussions with current International Cooperators have been positive and a more detailed determination of the level of effort and cost is underway.

The final Landsat status report was on a USGS Landsat benefit analysis study that will estimate the size and characteristics of mid-resolution imagery such as Landsat and evaluate the benefits of the use of the data.

Holly Stinchfield and **Natalie Sexton** [USGS—*Natural Resources Social Scientists*] described the first phase of the study that will enable a better understanding of the uses of moderate resolution imagery (e.g., Landsat), including those previously not captured or detailed. The survey team has identified over 22,000 e-mail addresses of potential data users and will use a snowball technique to further expand the survey size to reach an even broader user base. The effort is focused on identifying the broader societal benefits versus just cost benefits of moderate resolution imagery. **Rich Bernknopf** [USGS—*Economist*] provided additional information on the planned cost/benefit analysis and described a planned case study that will evaluate the economic benefit of resolving spatial and temporal uncertainty associated with crop production and greenhouse gas emission forecasting using moderate resolution imagery.

Anita Davis [NASA GSFC—*Education and Outreach*] and **Ron Beck** [USGS—*Land Remote Sensing Outreach*] concluded the Landsat session and gave an update to the team on their efforts to expand public awareness of the usefulness of Landsat data and to make remote sensing more prominent in educational programs.

LDCM Status

Bill Ochs [NASA GSFC—*Landsat Data Continuity Mission Project Manager*] and **John Dwyer** [USGS—*LDCM Project Scientist*] updated the team on LDCM development status. Ochs reported that the preliminary design review for the Operational Land Imager (OLI) was successful and that Ball Aerospace is doing an extraordinary job. The critical design review is scheduled for early fall. General Dynamics was awarded the spacecraft contract in April 2008 and the systems requirements review will be held in early fall.

The combined LDCM System Requirements Review/ Mission Definition Review/Preliminary Non-Advocate Review was held in May 2008. The review focused on ensuring that the functional and performance requirements and preliminary project plan satisfy the mission, and determined whether the proposed requirements, the mission architecture, and overall concept are complete, feasible, and consistent with available resources. The review highlighted several mission *strengths*.

- Project objectives are clearly aligned with Agency strategic goals and objectives.
- People managing and implementing the LDCM project are of exceptionally high quality with significant relevant experience, and the strong communications and trust between all participating agencies and contractors significantly improve the probability of success.
- The OLI instrument, spacecraft, and ground systems benefit from strong heritage from previous Landsat and other relevant NASA and non-NASA missions.
- LDCM is based on a comprehensive and stable set of requirements.
- The LDCM project and contractor have implemented a strong risk mitigation plan for the OLI instrument.

The review also identified the following three *issues*.

- The launch readiness date requirement of July 2011 results in an extremely aggressive, high-risk schedule, which lacks any schedule reserve at the mission level. As a result, the review team concluded that the probability of the LDCM project successfully implementing this schedule is extremely low.
- There is a requirement for the LDCM spacecraft to accommodate the addition of a thermal imaging instrument. The review panel concludes that adding a thermal instrument at this point would have significant cost and schedule impacts.
- Based on the schedule assessment, which identified the current baseline schedule as very high risk, independent mission cost assessments conclude that the current LDCM budget may not be adequate.

Ochs commented that at the previous meeting, two additional instruments were being considered as additional mission payloads: the Total Solar Irradiance Sensor (TSIS) and the Thermal Infrared Sensor (TIRS). In May 2008, NOAA announced that TSIS will be flown on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and is no longer an option for LDCM. However, based on continued Congressional interest, the project is ensuring that TIRS will not be precluded from being accommodated on LDCM.

Ed Grigsby [NASA Headquarters—*Landsat Program Executive*] elaborated on LDCM cost and schedule issues and the efforts to restore TIRS to the mission. He warned the Landsat Science Team that **there is a strong likelihood that the official LDCM launch date will be delayed 6–18 months** because of the independent cost and schedule assessments, along with NASA policy requiring launch readiness dates that meet a 70% likelihood probability. Five different independent reviews are nearing completion, and all agree that July 2011 is unobtainable, but the various models are yielding divergent results regarding how much additional time is needed. He said that a revised launch date would be announced in early Fall 2008. Grigsby added that the 6–18-month slip is just for the current baseline mission. If the decision is made to include a TIRS, there could be additional delays. He acknowledged that there has been growing Congressional interest in adding TIRS, but at this point, it is neither authorized nor funded.

Dwyer summarized the status of USGS LDCM ground systems development. Ground systems development and engineering support services contracts were awarded in March 2008, with Science Applications International Corporation (SAIC) undertaking the development effort and Stinger Ghaffarian Technologies (SGT), Inc. responsible for integration, testing, and calibration/validation tasks. The selection of a flight operations team contractor is in progress, and the engineering and design of a mission operations center is underway. The preliminary design of most of the ground systems elements is progressing, and the overall ground systems preliminary design review is targeted for December 2008. Of particular interest to the Landsat Science Team was the status of the LDCM Long Term Acquisition Plan (LTAP-8) and cloud detection plans. LTAP-8 was raised as an issue during the collection and acquisition element system requirements review. Since then, an LTAP-8 working group composed of USGS, NASA, and Landsat Science Team members has worked out roles and responsibilities and has developed an algorithm description document to define inputs, software components, decision rules and prioritization algorithm, and outputs.

Pat Scaramuzza [SGT, Inc./USGS/EROS—*Senior Scientist*] reviewed the status of research leading to an automated cloud detection strategy. LDCM plans call for a cloud mask that includes both the presence/absence of clouds and a confidence level for each measure. The research is focusing on an artificial thermal (AT) approach that uses visible and shortwave infrared inputs. The AT strategy is necessary because the thermal channel inputs used in the current Landsat automated cloud detection algorithm are not currently planned for LDCM. Several approaches to cloud detection have been tested using the AT concept and the results have been consistent with the current thermal-based cloud detection algorithm. Additional testing will take place before the operational algorithm is finalized and implemented. In addition,

development of a land/water mask will be explored, and Landsat Science Team members suggested investigation of shadow masking techniques and the role of the LDCM cirrus band in cloud detection.

Ed Knight [Ball Aerospace and Technologies, Inc.] presented a detailed summary of OLI technical requirements and development status. OLI is a pushbroom sensor with visible, near-infrared, and shortwave infrared capabilities and is based on a four-mirror telescope, front aperture stop with a focal plane assembly consisting of 14 sensor chip assemblies—all passively cooled. He provided a summary of major instrument requirements and concluded that testing thus far indicates sufficient margin is available on all specifications. The instrument's hardware is being constructed with considerable progress made on the optical bench, mirrors, electronics, and filters. Knight's conclusions were that OLI is on schedule, the key requirements and design specifications are stable, hardware is being delivered on schedule, and the preliminary data from focal planes and filters are all positive.

Tim Newman [USGS—*Principal Systems Engineer*] discussed a related topic—planning for Landsat 9. National Land Imagery Program (NLIP) aims *"to serve the Nation by acquiring and providing operational land imaging capabilities and applications to support U.S. economic, environmental, foreign policy, and security interests."* Central to NLIP is transforming Landsat into an operational program. With Landsats 5 and 7 aging, and LDCM development underway, planning for Landsat 9 must begin immediately. A formal requirements gathering and analysis process is needed. However, because of the urgency in initiating Landsat 9 planning, Newman reported on a notional review of mission concepts that assume similar capabilities to those of recent Landsat missions. Concepts being evaluated include following the traditional Landsat development model (i.e., developing a single large observatory along the lines of LDCM, with increased capability), cloning the LDCM design (i.e., taking advantage of current engineering developments), and using either single or multiple small satellites.

Landsat Science Team Science and Applications Reports

The second day of the meeting was devoted to science and applications reports by the Principal Investigators or their representatives. (All presentations are available at: *landsat.usgs.gov/science_july2008MeetingAgenda.php*.)

- *Monitoring trends in forest condition in the western United States using Landsat time-series data,* **Jim Vogelmann** [Arctic Slope Regional Corporation Research and Technology Solutions/USGS]
- *Update on tropical forest monitoring with Landsat image mosaics*, **Eileen Helmer** [U.S. Forest Service]
- *The promise of an open Landsat archive: A new era for landscape monitoring and management?*, **Robert Kennedy** [Oregon State University]
- *Benefits of the new Landsat data access policy*, **Alan Belward** [European Commission Joint Research Centre]
- *Interannual, multitemporal applications of Landsat to forest ecosystem monitoring and management*, **Randy Wynne** [Virginia Tech]
- *Monitoring forest change with Landsat and early rumblings on cirrus clouds*, **Curtis Woodcock** [Boston University]
- *Synergistic use of EOS/MODIS and Landsat/TM for mapping global forest carbon fluxes*, **Rama Nemani** [NASA ARC]
- *Cloud contamination in Landsat imagery: Current and future possible solutions*, **Sam Goward** [University of Maryland, College Park]
- *Advancing ice sheet research with the next generation Landsat sensor*, **Robert Bindschadler** [NASA GFSC]
- *Water resource assessment with LDCM*, **John Schott** [Rochester Institute of Technology]
- *Mapping drought and evapotranspiration at high resolution using Landsat/GOES thermal imagery*, **Martha Anderson** [USDA Agricultural Research Service]
- *Peace in the water rights world through Landsat thermal data*, **Tony Morse** [Idaho Department of Water Resources]
- *Developing ideal spectral signatures of irrigated areas for use in spectral matching techniques and decision trees*, **Prasad Thenkabail** [International Water Management Institute]
- *Developing consistent moderate resolution data products from Landsat and Landsat-like data*, **Feng Gao** [Earth Resources Technology, Inc./NASA]
- *A surface reflectance standard product from LDCM and supporting activities*, **Chris Justice** [University of Maryland]
- *Cloud detection challenges in LDCM*, **Lazaros Oraiopoulos** [University of Maryland Baltimore County/NASA]
- L*ong-term radiometric calibration: Can we extend consistent calibration parameters from Landsats 7 & 5 back through Landsats 1-4 MSS?*, **David Aaron** [South Dakota State University]

The collection of presentations provided strong evidence of the maturity of Landsat science and applications and showcased several crucial aspects of the Landsat mission design.

- Clear value is associated with access to the full Landsat archive containing consistent temporal coverage.
- While 16-day repeat capabilities are important, there is a need for increased temporal frequency.
- Major forestry and agriculture applications offer strong evidence of the necessity for shortwave

infrared observations, and there are significant examples demonstrating the importance of thermal infrared data for operational water and agriculture investigations.
- Experimental results show potential value of the planned LDCM aerosol blue band for water resources applications.
- Landsat offers a high level of geometric and radiometric consistency, including consistent calibration of all spectral bands. These traits aid all science and applications, especially studies of land change.
- Improved signal to noise performance and greater than 8-bit quantization will improve analytical results. (LDCM OLI data will be 12-bit.)
- The range of applications is expanding and will accelerate when full access to free data occurs over the next six months. The expanded use of Landsat to national, continental, and global land surveys is particularly noteworthy.
- There is increased acceptance that 30-m resolution is appropriate for both commercial and governmental resource management and land monitoring.
- There is a need to move to more robust product paradigms for map-quality data that are based on cloud- and shadow-free orthorectified surface reflectance data.
- Landsat data are increasingly integrated with other remote sensing geospatial datasets, and as no-cost data become available, the trend will accelerate.

At the end of the presentations, the Landsat Science Team concluded that the evidence of continuing expansion of the value and importance associated with Landsat's heritage in Earth observation, and the technical lessons learned by the Principal Investigators need to be presented to the broader science and applications community. The team's plan is to organize a special session at the Fall 2008 American Geophysical Union (AGU) meeting on *The Landsat Legacy in Understanding a Changing Earth*. In addition, the team will pursue the authorization of a special issue of a remote sensing journal on Landsat science and applications.

Landsat Science Team Discussion

The primary issues facing LDCM and Landsat are associated with maintaining long-term mission continuity without data gaps. While the reports on LDCM development progress were encouraging, and the progress on OLI was especially significant, NASA's consideration of a 6–18-month launch delay is troubling. Even though there is continuing Congressional support for TIRS, both the uncertainty of potential authorization and funding, and the chance of further delays in finalizing a decision regarding TIRS, is viewed as another threat to the earliest possible LDCM launch. The team concluded that thermal imaging is an important capability and that TIRS should be authorized as quickly as possible and an aggressive TIRS development schedule should be established so that there are no additional launch delays. However, as concluded during the January 2008 Landsat Science Team meeting, **schedule requirements should drive mission planning and decisions rather than the addition of more observation capabilities**.

There was also considerable discussion on the slow progress and apparent lack of Congressional support for the NLIP, which is considered to be critical to the establishment of an ongoing operational Landsat program. Because USGS views NLIP as the framework for moving ahead with Landsat 9 planning, this news is particularly troubling. Following a lengthy discussion, the Landsat Science Team concluded that Landsat 9 planning was already behind schedule and is now more urgent than NLIP authorization. The team recognizes the need to support NLIP since it will be the long-term framework for future Landsat-scale Earth observations. However, they believe that **priority must be given to Landsat 9**. The team also concluded that the Landsat science and applications user community must become more active in advocating for the earliest possible Landsat 9 launch.

Conclusions

The Landsat Science Team praised the plans and progress made to make the full Landsat archive accessible via the Internet at no cost. This bold and visionary move will have a profoundly positive impact on Landsat science and applications. In addition, the team stressed the importance of a global consolidated Landsat archive and urged forward progress. They also offered encouragement for the plans by NASA and the USGS to make GLS 2010 an international initiative, and endorsed the role of the CEOS LSI.

The importance of Landsat data continuity was reiterated, as it has been in previous meetings. Because of the importance of Landsat data continuity, **LDCM launch delays must be minimized and TIRS should not be pursued if it causes further launch delays**. In addition, the team concluded that because of the uncertainty in the LDCM schedule and capabilities, the uncertainty of NLIP, and the absence of concrete planning for Landsat 9, there is a strong need for broader community engagement on the needs of Landsat data users. The NLIP concept is critical since it is the framework for the future of moderate resolution imaging. However, the more urgent need is to move ahead on planning and developing Landsat 9. LDCM and Landsat 9 are key measures of success for achieving NLIP objectives.

The next meeting of the Landsat Science Team is tentatively scheduled for January 6–8, 2009, and will be hosted by the U.S. Forest Service in Fort Collins, CO. ■

meeting/workshop summaries

Summary of the 33rd Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Science Team Meeting

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The 33rd ASTER Science Team Meeting was held at TEPIA AOYAMA in Tokyo, Japan on June 9-12, 2008. ASTER Science Team members and other relevant participants attended the meeting. At the Opening Plenary, related projects were reported and issues to be addressed were reviewed. Splinter sessions of each working group followed, with reports from groups presented at the Closing Plenary. An ASTER Workshop was held on June 13, in conjunction with the ASTER Science Team Meeting. Approximately 100 participants from the ASTER science project team, private corporations, universities and research institutes, and other organizations participated. The workshop attendees heard 11 reports on research activities that showcased some of the practical applications of ASTER data.

Opening Plenary

H. Tsu [ERSDAC—*Japan ASTER Science Team Leader*] and **M. Abrams** [Jet Propulsion Laboratory (JPL)—*U.S. ASTER Science Team Leader*] made opening remarks. **M. Kato** [ERSDAC] explained the meeting schedule.

M. Abrams reported on behalf of **W. Turner** [NASA Headquarters] about the current status of NASA. His report covered NASA's organization, future projects, and budget. Abrams also included a detailed presentation of the Global Land Survey—which eagerly anticipates input from the ASTER team.

M. Abrams gave an update on the U.S. ASTER status. He introduced the follow-on missions, such as the Landsat Data Continuity Mission (LDCM) and Hyperspectral Infrared Imager (HyspIRI), and also reported on the recent urgent observation.

T. Sato [Japan Resources Observation System and Space Utilization Organization (JAROS)—*Instrument Team*] reported on the instrument status. He spoke about lifetime management of the instrument and explained the past operations and future plans for the Short Wave Infrared (SWIR) detector temperature rise.

M. Hato [ERSDAC—*Ground Data System (GDS)*] reported on GDS status. He gave an update of the production and distribution at GDS. Hato also reported the status of the ASTER Global Digital Elevation Model (GDEM) production and the issues related to temperature increase in the SWIR detector.

B. Bailey [U.S. Geological Survey Land Processes Distributed Active Archive Center (USGS LPDAAC)] reported on the distribution status at LPDAAC. He provided an update on the Direct Down Link (DDL) and the Expedited Data System (EDS).

M. Fujita [ERSDAC—*Science Scheduling Support Group (SSSG)*] presented the SSSG/Operations and Mission Planning (OMP) report. Fujita talked on the status of Global Mapping (GM) and GDEM Science Team Acquisition Requests (STARs) and the management of pointing device lifetime.

M. Abrams spoke on *Planet Action*, an initiative launched by Spot Image to provide geographic information for climate change related issues. The call for proposals is now open.

To close the plenary, **Y. Yamaguchi** [Nagoya University] raised two points for further discussion in the working groups:

- the impact that the Instrument team's proposed SWIR plan will have on each group; and
- the status of GM, night Thermal Infrared (TIR) GM, and other STARs.

Working Group Sessions

Level-1/Geometric/Digital Elevation Model (DEM) Working Group

In the first half of the session, the working group heard presentations about improvements to and validation results of ASTER Level-1 algorithm/software. Since the saturated SWIR channels prevents inter-telescope registration between Visible and Near Infrared (VNIR) and TIR, this situation should be corrected. The second half of the session was devoted to the ASTER GDEM project. **M. Hato** and **H. Fujisada** [Sensor Information Laboratory Corporation (SILC)] reported that GDEM processing operation is going well and the final products will be delivered at the end of October. **T. Tachikawa** [ERSDAC] and **B. Bailey** presented a future plan for validation of the GDEM.

Radiometric Calibration Working Group

The instrument team began the session with reports on results of onboard calibration efforts. Regarding VNIR and TIR, the team concluded that the radiometric database should be updated as soon as possible. **T. Tachikawa** reported three points on the problems and

countermeasures related to the SWIR issue. **A. Iwasaki** [University of Tokyo] presented the method for crosstalk correction using MODIS data. **H. Tonooka** [Ibaraki University] summarized his TIR recalibration method and **H. Yamamoto** [National Institute of Advanced Industrial Science and Technology (AIST)] reported on the recalibration implementation on the Global Earth Observation (GEO) Grid. Finally, **K. Arai** [Saga University], **A. Kamei** [AIST], **K. Thome** [University of Arizona], **H. Tonooka**, and **T. Matsunaga** [National Institute for Environmental Studies (NIES)] gave reports on the results of the 2007 field campaign and gave plans for the next field campaigns.

Atmospheric Correction Working Group

B. Eng [JPL] gave a status report of the current Level-2 software, *Version 3.1*. The next version, *Version 3.2*, will be delivered in June 2008. **H. Yamamoto** reported on validation and the updated Look-Up Table (LUT) related to water vapor. **M. Arioka** [AIST] reported on the ongoing estimation of cloud-free ASTER data availability. The data will be used to develop new cloud cover assessments on the GEO Grid.

Temperature-Emissivity Separation (TES) Working Group

In the first half of the session, the group heard reports on the status of the nighttime TIR STAR. This working group agreed to request Operation and Mission Planning (OMP) to continue the current operation. The second half of the session consisted of many presentations on the applications of TES products. **H. Tonooka** and **S. Hook** [JPL] presented the efforts to develop an emissivity database. There was discussion about the impact the missing SWIR is having on the TES working group. The increase of error in the TIR emissivity correction and inter-telescope registration will cause effects.

SSSG/OMP Working Group

M. Fujita reported on the third round of GM, the nighttime TIR GM, the Gap filler STAR, and the GDEM STAR. **M. Abrams** classified the observation resources at present into four categories. The group reviewed the appropriateness of resource allocation for each category and decided to continue with the current practice until the end of August. The subsequent allocation will be determined later, considering the data acquisition status after September. **T. Sato** outlined the SWIR recycle status and plan. JAROS will prepare and try the SWIR cooler *on/off* procedure. The science team will develop a validation plan just after the process.

STAR Committee

There was a report on the STAR Tool problem. Details will be investigated.

Ecosystem/Oceanography Working Group

After a review of the STAR status, the group heard eight research reports. The team also discussed the impact the missing SWIR will have on science. Three specific impacts were raised:

1. SWIR Band 4 is necessary for soil water content and biomass evaluation;
2. SWIR bands are used in Apparent Thermal Inertia (ATI) calculations; and
3. cloud assessment and cloud/snow discrimination will be significantly impacted.

Geology/Spectral Working Group

There were presentations on eight research activities in the fields of geology, glaciology, and volcanology. Following the presentations, the group focused on two issues:

1. Publishing a white paper for VNIR/SWIR/TIR; and
2. Monitoring of a day/night TIR pair for glacier analysis.

Finally, the group raised a **new action item**: rearrangement of the volcano STAR/Data Acquisition Request (DAR). ■

meeting/workshop summaries

May 2008 AGU Joint Assembly A-Train Special Sessions Overview

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The 2008 Spring AGU Joint Assembly meeting was held from May 27-30 in Ft. Lauderdale, FL. At this meeting, there were five special sessions and a union session devoted to results obtained from the A-train constellation of satellites. The A-train currently consists of five satellites that fly in formation in an afternoon orbit with an equator crossing time near 1:30 local time. These satellites are NASA's Aqua, Aura, CloudSat, and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), and the French Space Agency's Polarization and Anisotropy of Reflectances for Atmospheric Sciences Coupled with Observations from Lidar (PARASOL) which houses the POLarization and Directionality of the Earth's Reflectances (POLDER) instrument. The operating instruments on Aqua are the Atmospheric InfraRed Sounder (AIRS), the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), the Advanced Microwave Sounding Unit A (AMSU-A), Clouds and the Earth's Radiant Energy System (CERES), and the Moderate Resolution Imaging Spectroradiometer (MODIS). Aura is comprised of the High Resolution Dynamics Limb Sounder (HIRDLS), the Microwave Limb Sounder (MLS), the Ozone Monitoring Instrument (OMI), and the Tropospheric Emission Spectrometer (TES). In addition to the union session entitled **Taking the A-train**, *the special sessions, consisting of both oral and poster sessions, were:*

1. The A-Train and Field Experiments: Upper Troposphere and Stratosphere Aerosols, Clouds, and Composition
2. What We Have Learned About Aerosol Composition from A-Train Measurements
3. Measuring and Assessing Air Quality
4. Cloud Properties Derived From Multiple Sensors
5. Aerosol, Cloud, and Precipitation Interactions

A summary of the meeting follows. For the sake of brevity, only a portion of the talks are summarized here.

May 27

The meeting opened with the A-train union session. There were five invited talks in this session related to each of the five special sessions. **Mark Schoeberl** [NASA Goddard Space Flight Center (GSFC)] and **Anne Douglass** [NASA GSFC] presided over the session**. Joanna Joiner** [NASA GSFC] and **Gerald Mace** [University of Utah] discussed how the combination of A-train cloud measurements from MODIS, CloudSat, CALIPSO, OMI, MLS, and POLDER have improved our understanding of clouds and radiative transfer in cloudy conditions. **Jonathan Jiang** [NASA/Jet Propulsion Laboratory (JPL)] discussed how MLS observations of carbon monoxide (CO) can be used to distinguish clean from polluted clouds and how other sensors such as MODIS, AMSR-E, Tropical Rainfall Measuring Mission (TRMM), CloudSat, and CALIPSO can be used to examine the effect of pollution on cloud properties and precipitation. **Wallace McMillan** [University of Maryland, Baltimore County (UMBC)] described how a number of A-train instruments, including AIRS, TES, and OMI, were used to monitor air quality during an intensive campaign in Texas. **Omar Torres** [Hampton University] closed the session with a talk focused on deriving aerosol properties using OMI and other A-train sensors including MODIS.

The afternoon included two oral sessions on measuring and assessing air quality. **Bryan Duncan** [NASA GSFC], **Annmarie Eldering** [NASA/JPL], **Pieternel Levelt** [Koninklijk Nederlands Meteorologisch Instituut (KNMI)] and **James Szykman** [NASA Langley Research Center (LaRC)] presided over these sessions. They included several invited talks. **Randall Martin** [Dalhousie University] discussed how remotely sensed satellite data, including nitrogen dioxide (NO_2) from OMI, can be used to monitor surface air quality. **Rob Pinder** [National Oceanic and Atmospheric Administration (NOAA)/U.S. Environmental Protection Agency (EPA)] presented a method for evaluating a satellite-based NO_x emission estimate using a photochemical model, direct sensitivity calculation, and an inverse modeling technique. **Pepijn Veefkind** [KNMI] presented a method of combining OMI NO_2 and MODIS aerosol data with surface *in-situ* observations, creating a high spatial resolution dataset for Northwestern Europe. There were also a number of interesting general contributions: **Robert Chatfield** [NASA Ames] showed that estimates of lower tropospheric ozone can be obtained using OMI and MLS. **Thomas Kurosu** [Harvard Smithsonian Observatory] showed results from the latest OMI retrievals of formaldehyde (HCHO) and glyoxal (CHO-CHO). These are volatile organic compounds that are pollutants and also contribute to the formation of tropospheric ozone. **Nick Krotkov** [UMBC] gave examples of what has

been learned about global sulfur dioxide (SO_2) from OMI. **Greg Osterman** [JPL] showed how air quality models can be evaluated and improved using data from A-train instruments. In addition to the two oral sessions, there were 14 posters in the poster sessions.

May 28

Wednesday morning opened with an oral portion of *The A-Train: Aerosol, Cloud, and Precipitation Interactions: Measurements and Modeling* presided over by **Jonathan Jiang** and **Sandra Yuter** [North Carolina State University]. **Jean-Pierre Blanchet** [University of Quebec at Montreal] gave an invited talk in which he discussed the impact of sulfuric acid (H_2SO_4) coating on aerosols. The presence of H_2SO_4 reduces the number of ice nuclei compared to uncoated particles. When coupled with a cold low and slow rising motion, H_2SO_4 coated particles yield large ice crystals which sediment out quickly. The result is a depletion in water vapor and greenhouse cooling. **James Coakley** [Oregon State University] described how satellite retrievals show aerosol optical depth and fine mode fraction increases near the edges of clouds. These retrievals, however, are incorrect. The errors result from two competing physical effects: 1) There is a ~3% increase in relative humidity (RH) levels within 1 km of a cloud—this increased RH makes aerosol particles larger; and 2) Three-dimensional cloud effects scatter sunlight sideways and the scattered sunlight then scatters off atmospheric molecules back up to the satellite causing an apparent *bluing* of aerosols—i.e., it makes aerosols look smaller than they actually are. There is good agreement between MODIS and CALIPSO retrievals of aerosol optical depths for relatively large cloud-free areas where cloud edge effects do not occur. **Jingfeng Huang** [University of Miami] examined correlation of increased aerosols and suppressed precipitation in the west African monsoon using Total Ozone Mapping Spectrometer (TOMS) and GCPC data for the period 1979-2000 and MODIS and TRMM data for the period 2000-2007.

There were four A-train poster sessions in the afternoon. Here, we summarize some of the poster talks from *The A-train and Field Experiments: Upper Troposphere and Stratosphere Aerosols, Clouds, and Composition* special session. **Marcella Ulate** [University of Costa Rica] compared model temperature and wind fluctuations near the tropopause to observations during the Tropical Composition, Cloud and Climate Coupling (TC4) mission in Costa Rica. **Ling Wang** [NorthWest Research Associates] compared temperature retrievals from the Aura/HIRDLS and the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC)/Challenging Minisatellite Payload (CHAMP) radio occultation experiments during the Northern Hemisphere 2008 minor stratospheric sudden warming event. **Sun Wong** [Texas A&M University] presented cloud top measurements from the CALIPSO experiment in conjunction with MLS water (H_2O) and ozone (O_3) measurements to investigate the influence of mid-latitude convection on the summertime hydration of the lower stratosphere. **Thien Lee** [Iowa State University] compared Aura water vapor measurements with Global Forecast System (GFS) and North American Mesoscale (NAM) model analyses in the upper troposphere / lower stratosphere. **Andrey Savtchenko** [NASA GSFC] discussed the seasonal, zonal, and latitudinal variations of deep convection based upon analyses of cloud top pressures from the MODIS, POLDER, and AIRS experiments, and the atmospheric humidity and outgoing long wave radiation fields from AIRS. **Eric Shettle** presented calculations and infrared measurements of smoke in the stratosphere, as observed by the Halogen Occultation Experiment (HALOE), and also discussed CALIPSO, MLS CO, and OMI aerosol index measurements corresponding to the fire plumes originating in Australia during December 2006. **Remco Braak** (KNMI) discussed a multi-wavelength OMI algorithm by which OMI aerosol measurements can be used to distinguish between desert dust, biomass burning, and sulfates. **Dennis Hlavka** [NASA GSFC] compared extinction profiles from the Cloud Physics Lidar (CPL) onboard the ER-2 aircraft during the summer 2006 CALIPSO/CloudSat Validation Experiment (CCVEX) to CALIPSO measurements. **Lei Bi** [Texas A&M] presented calculations of the scattering properties of nonspherical dust-like aerosols and used the scattering properties to calculate the influence of these aerosols on top of atmosphere radiances. **Jeng-Hwa Yee** [Applied Physics Lab] presented initial results of comparisons of a prototype Geostationary Imaging Fabry–Perot Spectrometer (GIFS) with CALIPSO data and the NASA/Langley Lidar on the Langley B200 aircraft. **Timothy Berkoff** [UMBC] discussed ground-based lidar measurements obtained during the CALIPSO and Twilight Zone (CATZ) Campaign.

Wednesday afternoon also included the oral portion of the special session on *What We Have Learned About Aerosol Composition from A-Train Measurements.* Highlights of this session included a talk by **Chip Trepte** [NASA Langley Research Center (LaRC)] on the developing aerosol climatology from the CALIPSO space-based lidar. Trepte discussed the evolution of the CALIPSO algorithms and showed the consistency between day and nighttime aerosol optical thickness retrievals. **Jens Redemann** [Bay Area Environmental Research (BAER) Institute] considered over-ocean aerosol fine mode fraction (FMF) from MODIS and CALIPSO, showing that the FMF from MODIS along the CALIPSO track was generally representative of the FMF over the entire MODIS swath. These results suggest that CALIPSO retrievals of aerosol properties may be representative of larger regions. **Irina Sokolik**

[Georgia Institute of Technology (Georgia Tech)] discussed dust aerosol transport modeling and highlighted differences in simulated dust distributions for ensembles of simulations where dust injection height was varied. Sokolik pointed out much higher dust aerosol optical thickness over source regions than is observed in Deep-Blue MODIS Aqua observations, and also showed how CALIPSO might misclassify high dust concentrations as thick clouds. **Olga Kalashnikova** [NASA/JPL] discussed dust IR signatures, with implications for temperature retrievals from AIRS. **Peter Colarco** [NASA GSFC] presented an evaluation of sampling strategies for comparing satellite-to-model aerosol properties.

A poster session was also part of this session. See the table below for details on some of the posters.

May 29-30

Thursday morning continued the oral session on *The A-Train: Aerosol, Cloud, and Precipitation Interactions: Measurements and Modeling*. Friday morning opened with the oral session on cloud properties derived from multiple sensors; **Joanna Joiner** and **Steven Platnick** [NASA GSFC] presided over this session. The session began with three invited talks. **Steven Massie** [National Center for Atmospheric Research (NCAR)] showed that HIRDLS can profile cirrus clouds similar to CALIPSO. Massie also discussed how various A-train sensors see the tops of clouds differently. **Robert Austin** [Colorado State University] discussed how MODIS and CloudSat data have been combined to produce a number of unique products including liquid and ice water content and profiles of cloud optical extinction. **Jerome Riedi** [University of Lille] described two types of cloud pressure retrievals from POLDER: one using the oxygen A-band and a second using Rayleigh scattering. The multi-angle POLDER measurements provide information on cloud geometrical thickness and the existence of multiple cloud layers. **Ralph Kuehn** [University of Wisconsin] showed comparisons between MODIS and CALIPSO cloud optical depths. Kuehn noted that MODIS doesn't see clouds with optical depths between 0.1 and 0.3. **Pepijn Veefkind** [KNMI] presented comparisons between OMI cloud pressures derived from oxygen dimer absorption (which provides a value in the middle of a cloud) and the *cloud midpoint* as defined by the CloudSat cloud mask. The correlation between the two was about 0.5. Veefkind noted that for low clouds, both OMI and POLDER retrieve higher clouds than MODIS.

In the afternoon, **Eric Jensen** [NASA Ames] and **Steven Massie** presided over the oral portion of *The A-train (and Field Experiments): Upper Troposphere and Stratosphere Aerosols, Clouds, and Composition* special session. **Henry Selkirk** [NASA Ames] discussed the characteristics of wave motions in the tropical tropopause layer and their effects on the vertical structure of temperature, winds, and trace constituents over Central America during the TC4 campaign in 2007. **Leonhard Pfister** [NASA Ames] presented a number of subvisible cirrus cloud cases, folding temperature analyses, temperature soundings, and A-train cloud and water vapor data to understand the history of the air in which the cloud is observed. About half of the thin cirrus within 1 km of the tropopause were shown to have recent convection (i.e., within 7 days) in their history, even in a region where most convective tops were 1 or more km below the tropopause. **Eric Jensen** presented a comparison of CALIPSO cloud extinction frequencies with those calculated from simulations with standard microphysics and from simulations with ice concentra-

Topic of Poster	Presenter	Affiliation
Work on aerosol transport modeling	Huisheng Bian	Goddard Earth Science and Technology (GEST) Center, UMBC
Consistency in aerosol composition from models and CALIPSO retrievals	Ellsworth Welton	NASA GSFC
Dust characterization during the NASA African Monsoon Multidisciplinary Analyses (NAMMA) campaign	Myeong-Jae Jeong	GEST Center, UMBC
Aerosol spectral absorption and scattering over Bermuda	Kenneth Voss	University of Miami
Analysis of Asian dust using A-train and ground-based measurements	Hyung-Jin Choi	Georgia Tech
The effects of biomass burning aerosols	Jimena Lopez Jeffrey Timmerman	BAER Insitute University of Virginia

tions artificially reduced to produce better agreement with *in situ* measurements. **Steven Massie** related cirrus observed by the HIRDLS experiment to MLS relative humidity with respect to ice (RHI), Climate Diagnostic Center outgoing longwave radiation (OLR), and the Kelvin wave temperature perturbations in a discussion of cirrus and its formation mechanisms. **Steven Platnick** presented an update on the performance and use of the MODIS Airborne Simulator (MAS) and MODIS/ASTER Airborne Simulator (MASTER) imagers during TC4. Along with ongoing in-flight instrument characterization, the imager team is working with other ER-2 sensors [e.g., Cloud Radar System (CRS), ER-2 Doppler Radar (EDOP), Cloud Physics Lidar (CPL), Solar Spectral Flux Radiometer (SSFR)] in developing merged datasets, cloud retrieval comparisons (i.e., cloud optical properties and water path), and radiative consistency and closure studies. **Bruce Kindel** [University of Colorado] discussed how MAS retrievals of cloud optical depth and effective radius during TC4 were used in a three-dimensional radiative transfer code to model cloud albedo. The calculated spectral irradiances and albedos were compared to measurements from the ER-2 SSFR and found to be in close agreement, validating the retrieved ice crystal effective radii that ranged from 25-40 μm. **Melody Avery** [NASA Ames] explained that during TC4 many hours were spent by instruments on the NASA DC-8 sampling the upper troposphere in a region of expected intertropical convergence zone (ITCZ) convective outflow. Statistical distributions of ozone and cloud water content indicate there is an estimated 50% convective turnover of the troposphere, below the tropical tropopause transition layer, with a consequent minimum in ozone at about 10 km consistent with measured profiles of bromine-containing marine gases that can be used as boundary layer tracers.

John Gille [University of Colorado/NCAR] and **Mark Olsen** [UMBC] presided over a second oral portion of *The A-train (and Field Experiments): Upper Troposphere and Stratosphere Aerosols, Clouds, and Composition*. This session closed out the meeting. **Brian Kahn** [NASA/JPL] discussed the seasonal, latitudinal, and height differences in relative humidity within and outside of ice clouds based upon analyses of the temperature, water vapor, and cloud profiles that are observed by AIRS, CALIPSO, and CloudSat. **Hui Su** [NASA/JPL] presented calculations of cloud radiative forcing and cloud-induced heating rates, with a focus on cirrus in the tropical tropopause layer (TTL), based upon observations from CloudSat, CALIPSO, and Aura MLS**. Lamont Poole** [NASA/LaRC] presented polar stratospheric cloud classification schemes based on CALIPSO lidar data. **John Gille** presented case studies of low ozone intrusions in the lower stratosphere using HIRDLS observations as well as the Whole-Atmosphere Community Climate Model, *version 3* (WACCM3) model simulations. **Mark Olsen** discussed the January 2006 intrusion of low ozone air observed by the HIRDLS experiment over North America. Observations were compared to Global Modeling Initiative (GMI) model calculations. **John Worden** (NASA/JPL) presented new satellite measurements of vertically resolved troposphere ozone profiles from the Aura/TES experiment that revealed enhanced summertime tropospheric ozone between 80 and 100 parts per billion [ppb] over North-East Africa, the Mediterranean, the Middle East and central Asia at approximately 450 hPa. **Michelle Santee** [NASA/JPL] discussed chemical processing and dispersal of chemically-processed air, using MLS measurements of nitric acid (HNO_3), H_2O, and O_3 from the subvortex (i.e., the transition zone between the region above strong confinement inside the polar vortex and the region below less restricted exchange) with lower-latitude air. **Andrew Dessler** [Texas A&M] related CALIPSO TTL cloud frequencies of different optical depths to outgoing longwave radiation and sea surface temperatures. ■

MODIS-VIIRS Science Team Meeting Summary

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The first joint meeting of the Moderate Resolution Imaging Spectroradiometer (MODIS) Science Team and the Visible Infrared Imager Radiometer Suite (VIIRS) Science Team was held May 13-16, 2008, in Linthicum Heights, MD. Having a combined meeting was deemed a logical step since the VIIRS instrument continues most of the capabilities of the MODIS well into the future. In addition, several people are on both science teams. A summary of the plenary sessions is provided here. The meeting agenda, presentation slides, and meeting minutes for all sessions of the meeting are available on the MODIS web site at *modis.gsfc.nasa.gov/sci_team/meetings/200805/*.

Plenary Sessions

Jack Kaye [NASA Headquarters] provided an overview of NASA Earth science programs and their future. Fourteen missions are flying, many in the extended phase, and two launches are coming up. The next senior review of extended missions is to be in 2009. Work also continues with airborne platforms, field work, and modeling. The recent Intergovernmental Panel on Climate Change (IPCC) assessment reflects what NASA programs are enabling. The 2009 budget includes funding for the decadal survey missions. The National Oceanic and Atmospheric Administration (NOAA) received funding to bring back de-manifested sensors on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP). NOAA was also funded to support climate data records. On an interagency level, NASA contributes to three administration-level programs: the U.S. Climate Change Science Program (CCSP), the ocean initiative, and the intergovernmental Group on Earth Observation (GEO) effort.

Paula Bontempi [NASA Headquarters] provided an overview of challenges and successes for the MODIS Science Team since the last meeting. During the Earth Observing System (EOS) recompete, 322 proposals were received, and 122 selected to be supported at $26 million per year. The challenge for future research is to reap the full research benefits of MODIS, combined with other sensors, to create a new understanding of the Earth and feed decision support systems. The science team needs to migrate data products to core production for climate data records and to develop new products. NASA will undertake another strategic plan in 2009, allowing MODIS and MODIS-type observations to be blended into the science plan. NASA is changing from mission-oriented teams to measurement-oriented teams. Headquarters is now implementing some mission concept studies, as recommended in the decadal survey that was released in January 2007. Headquarters will also be looking for merged data products, new products, and linkages to NPP VIIRS in the future. Bontempi provided an overview of missions that are being formulated or are nearing implementation. The science team should weigh what new measurements are needed and which of these can feed into future missions. There are opportunities for novel new missions or small missions that could be gap fillers.

Diane Wickland [NASA Headquarters] offered background for the NPP—a "bridge mission" between EOS missions and NPOESS to provide continuity for systematic measurements. NPP will provide operational data for weather forecasting and science research, but is not planned to do everything that MODIS does. Wickland provided an overview of the products that will continue and those at risk. Time series data products will serve a variety of science disciplines. The NPP launch was re-baselined to June 2010, and the budget has been reprofiled. The Ozone Mapping and Profiler Suite (OMPS) Limb sensor has been restored, and a Clouds and the Earth's Radiant Energy System (CERES) instrument has been added. Product Evaluation and Test Elements (PEATEs) were asked to scope potential data production options. The NPP science team needs to evaluate the quality and character of environmental data records. Wickland requested a concise summary of environmental data records in the next six months. In the near term, NASA's role in NPP calibration and the validation of science-quality environmental data records will be determined. Headquarters is considering what will happen to the NPP science team after launch. Funding expires six months after launch, which is probably not enough time to evaluate products.

Vince Salomonson [University of Utah] and **Jack Xiong** [NASA Goddard Space Flight Center (GSFC)] reported that both MODIS instruments are performing nominally. Both instruments have seen some changes in the reflectance of the optics and the solar panels. These changes amount to about 40% since launch for the Terra MODIS, and about 20% for the Aqua MODIS at the shortest wavelength (412 nm) channel. However, these changes have been accommodated well, and both instruments are meeting calibration and characterization specifications. Salomonson provided an overview of the status of noisy detectors, Terra and Aqua MODIS spectral characterization results, and spatial characterization results. Aqua has a known misregistration of about 0.3 pixel between bands on the cold focal

plane assembly (FPA) and warm FPA, but this has not proved to be a problem. The science team will be studying calibration consistency between Terra and Aqua MODIS and cross-sensor calibration of MODIS with other sensors. MODIS data production and archiving are done through distributed systems. *Collection 5 (C5)* is nearly completed for both the Terra and Aqua MODIS data products. *Collection 6 (C6)* is underway for Level 1 data.

The number of refereed, technical MODIS-related publications continues to grow at a rate of well over one refereed publication per day. More than 2,000 MODIS-related papers have been published, with more than 300 published in 2008. There is great anticipation for the VIIRS instrument, which will continue much of the MODIS capabilities. With products to come from the future VIIRS instruments, the importance of reprocessing in maintaining and improving the quality of these products needs to be kept in mind.

Jim Coakley [Oregon State University (OSU)] discussed Cloud-Aerosol Lidar and Infrared Pathfinder Satellite (CALIPSO) and MODIS observations of changes in aerosols near clouds. These changes in aerosols influence direct radiative forcing and present the biggest uncertainty in climate change. Aerosols are responding to clouds; clouds have an indirect effect on aerosol forcing. MODIS and CALIPSO coincident observations are valuable in studying the effect. Aerosol indirect radiative forcing causes the droplet radius to decrease as optical depth increases. Reanalysis shows an increase in cloud cover with increased aerosol burdens. Near clouds, aerosol burdens are going up, and aerosols are getting bigger in both Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) and MODIS measurements.

Bryan Baum [University of Wisconsin] outlined the NPP's science goals and the need to access algorithms for environmental data records. In developing long-term data records, it is important to track the needs of the user communities and pay attention to details like orbital drift, calibration, trace gases changes, spectral shifts, improvements in radiation transfer (RT) models, changes in ancillary data, sampling, and sensor-specific issues. A significant issue for the transition from EOS to NPP is that heritage algorithms are not static, while NPOESS algorithms are. The PEATE provides a possible way to transition from EOS to NPP. MODIS code transition to the atmosphere PEATE is progressing. Baum wants to put all algorithms through the PEATE to be able to compare MODIS algorithms with VIIRS algorithms. The PEATE is useful in refining products. Climate data records will require several passes through the PEATE.

Chris Justice [University of Maryland] provided an overview of the land team's activity since 2006. The land team has started to move from missions to measurements. The last VIIRS meeting, held at the National Climate Data Center (NCDC) in February 2008, focused on validation planning. MODIS land data are well-established and used, and there has been a large uptake by the international community. MODIS is providing a major contribution to the Global Earth Observation System of Systems (GEOSS) and is setting a global standard for data quality, validation, product and instrument information, and data availability. *C5* reprocessing of land products finished in May 2008. *C6* processing is in the planning stage. MODIS is being used in disaster management activities and by operational users. The land community continues to get increased user feedback on standard products. The user community expects continuity with VIIRS data. The land direct-readout community is growing and a land focus group is self-organizing around MODIS. Outside of the science team, the land community needs more information about the VIIRS instrument and what science products can be expected. The land part of the VIIRS science team has good communication with NOAA and the Integrated Program Office (IPO). The land group evaluation of the proposed VIIRS environmental data records is continuing. Instrument overlap with MODIS will be essential.

Chuck McClain [NASA GSFC] highlighted new science from the ocean community. Mike Behrenfeld [OSU] provides a new tool to study ecosystem structure with the development of a new product for fluorescence line height (FLH). Fluorescence yield compared to dust deposition shows a correlation between dust and ocean color. The ocean group has worked to improve MODIS ocean color data. There are significant differences between Terra and Aqua MODIS. The ocean team tried to eliminate scan artifacts from retrievals. The ocean team used the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) to characterize Terra data, bringing Terra's response in line with expectations. The VIIRS ocean team has focused on the sensor's performance over the last year and a half. McClain listed the ocean biology processing group's datasets and mission support activities. The ocean group is planning to reprocess ocean products and is considering a revision of aerosols models. A robust ocean color web site is being maintained and is distributing an increasing amount of data. The web-based forum is used to communicate with the community.

Bob Evans [University of Miami] provided an overview of the status of sea-surface temperature (SST) products and continuity with VIIRS. He described ongoing work on the MODIS SST product, which uses Aqua and Terra match-ups versus time by latitude band. There are a relatively small number of retrievals per 25 kilometer pixel over the full mission. Quality tests are improving since past quality tests rejected

more high-temperature pixels. The ocean team is working to correct Terra mirror side offset issues. MODIS SST measurements are being compared with National Institute of Standards and Technology (NIST) standards and related satellite measurements from other instruments. The Marine-Atmosphere Emitted Radiance Interferometer (M-AERI) had been deployed on research vessels and a cruise ship through December 2007. The team is comparing VIIRS and MODIS SST algorithms and will later use instrument tests to compare the VIIRS instrument to MODIS.

Bruce Guenther [NOAA/IPO] provided an update on VIIRS and calibration and validation planning. He showed and discussed the VIIRS management structure. The organization, featuring a principal contractor with a science advisory team, is different than what the NASA team is accustomed to. The IPO calibration and validation (cal/val) funded activity is led by user community experts. Cal/val activities are proceeding on schedule. A senior science review concluded that VIIRS appears to be an effective sensor. The review suggested some improvements, with one recommendation limiting specification compliance to fields of view within 45° of nadir. Edge scan performance should not drive the schedule or cost. The review provided recommendations for flight unit one testing. VIIRS sensor performance was compared to MODIS and SeaWiFS, indicating that VIIRS has a more reduced bandset than MODIS. Guenther described the noise in VIIRS reflected solar and thermal emissive bands. A significant amount of test data on the VIIRS engineering development unit (EDU) has contributed to understanding the performance of Flight Unit 1 (FU1) in advance of its testing. NIST is working on developing new test fixtures, most likely for Flight Unit 2 (FU2). Guenther discussed known issues on FU1. Optical cross-talk is occurring in the visible and near infrared integrated filter assembly (IFA). The problem will likely impact ocean color and aerosol optical thickness (AOT). Guenther asked for feedback on the 1.268 micron band, which saturates at 130 $W/m^2/sr/\mu m$.

Rick Stumpf [NOAA] described the use of satellite imagery for monitoring and understanding harmful algal blooms. Harmful algal blooms (HABs) are toxic, noxious, or nuisance blooms that kill fish and impact shellfish, tourism, and human health. They also cause financial losses. HABs occur globally, but many cannot be detected. Colored blooms have a high biomass and are visible. It is possible to identify a bloom as a HAB or a non-HAB by its relationship with other species, temperatures, etc. Factors to consider when identifying a bloom include brightness, chlorophyll change, specific optical characteristics, and seasonal or climatic associations.

Tom Maiersperger [Science Applications International Corporation (SAIC)] reported on the Land Processes Distributed Active Archive Center (LP DAAC). The LP DAAC is part of the Earth Observing System Data Information System (EOSDIS) and is located at the U.S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center (EDC). The LP DAAC archives and distributes MODIS and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) products. The historic trend in user demand is increasing. The LP DAAC has distributed 30 million products to date. It routinely distributed one million science granules per month in early 2008. The EOSDIS will be re-architecturing the EOSDIS Core System (ECS). The LP DAAC is moving towards maintaining an online archive instead of the data pool, which contained a one-year rolling archive. The LP DAAC is supporting faster MODIS *C5* reprocessing by ingesting data more quickly through a number of access methods. The EOS data gateway is transitioning to ECHO/WIST, the general user interface (WIST) for the middleware between Data Partners and Client Partners (ECHO). Other access methods include the LP DAAC data pool, the Global Visualization Viewer (GloVis), a spatial subscription service, and a machine-to-machine gateway. MRTWeb, built on the MODIS Reprojection Tool (MRT), is a new access tool available in 2008. It adapts and integrates two familiar tools, GloVis and MRT, and allows projecting and mosaicing. A user working group recommended that the LP DAAC pursue new data holdings to make up and extend the land remote sensing record, facilitate meetings between USGS and NASA to develop a long-term MODIS and ASTER archive, and expand the visibility of alternative data access methods.

Ed Masuoka [NASA GSFC] reported on the Level 1 and Atmosphere Archive and Distribution System (LAADS). LAADS added a Level 2 browser for atmospheres and offers a Level 3 browser. LAADS is distributing about 3 TB of data per day (400,000 files) to the public, with distribution about even between Aqua and Terra. Distribution is possible because files are online. All MODIS Level 1B data will be available online by September to free up production on demand. The MODIS Data Processing System (MODAPS) production is finishing *C5*. The end of *C5* will drop the X-rate and free up bandwidth to serve data to the public. MODAPS is starting atmosphere *Collection 5.1 (C5.1)* reprocessing. At the end of the year, MODAPS will begin science testing for *C6*. Masuoka discussed *C6* land and atmosphere processing rates.

Ruth Duerr [NOAA/National Snow and Ice Data Center (NSIDC)] provided an overview of the NSIDC, located at the University of Colorado. NSIDC's mission is to contribute to cryospheric science, manage

data, and disseminate information about snow, ice, and permafrost. NSIDC had a copy of the EOSDIS Core System and is re-architecting the ECS data system. NSIDC is moving toward an online archive. All *C5* and some *Collection 4 (C4)* products are available online now. Orders for MODIS data products are increasing. The number of distinct MODIS users is also growing. The number of granules ordered increased this year. Users only recently switched to *C5*. NSIDC has other MODIS-based products in addition to core products. These include surface morphology and snow grain size of Antarctica, a blended snow product, and MODIS-enhanced radar. NSIDC is offering new web services with a map-server interface to the mosaic of Antarctica. A MODIS interactive subsetting toolkit was developed to provide easier access to MODIS data over specific stations. All improvements were based on user requests.

Hassan Oudrari [Science Systems and Applications, Inc. (SSAI)] presented VIIRS sensor performance and explained that testing is still ongoing. Pre-thermal vacuum testing was scheduled to start no earlier than August 1 and thermal vacuum (TV) testing is scheduled to start in December 2008. VIIRs bands and products were compared to bands and products from MODIS. VIIRS sensor hardware incorporates a modular approach. All VIIRS bands meet signal-to-noise ratio (SNR), noise equivalent delta radiance (NEdL), and noise equivalent delta temperature (NEdT) specifications. All bands, except three, meet the dynamic range and transition requirements. All reflective and thermal emissive bands meet the response versus scan (RVS) characterization uncertainty. Stray light rejection (SLR)—light coming in from off the field-of-view—causes contamination of radiance. SLR shows non-compliance for four bands. A waiver is proposed to relax SLR requirements. An impact assessment needs to be done using MODIS and/or synthetic data to determine how the SLR non-compliance will affect environmental data records (EDRs). The *near field response*—the amount of radiation coming into sensor from bright targets—is not in compliance for many bands. The overall VIIRS out of field scattering is at least as good as was obtained on MODIS. A waiver was proposed for limiting radiance values for bright targets. Ghosting is observed for many short-wave infrared (SWIR), near infrared (NIR), and long-wave infrared (LWIR) bands. An assessment of the impact on EDRs is ongoing. A VIIRS polarization analysis is ongoing, but preliminary results show compliance. All VIIRS bands meet band-to-band registration specifications for intra M-bands and intra I-bands. Dynamic crosstalk, seen when scanning from bright to dark targets, leads to signal contamination in other bands. The static electric crosstalk specification is tight and is not met for all VIIRS bands. Based on EDU crosstalk analysis, crosstalk specifications are being reviewed to make them consistent, realistic, and specific to each crosstalk type. Based on ambient test results, FU1 optical crosstalk is significant for many visible near infrared (VisNIR) bands. Three major VIIRS issues include: thermal emissive calibration not meeting specifications for three bands; reflective band uniformity showing noncompliance for many bands; and ghosting occurring in FU1 emissive bands. The impact on EDRs is still to be completed. Transition noise and non-linearity are leading to specification non-compliance.

Jack Xiong discussed VIIRS FU1 pre-launch calibration and characterization. All detectors meet the SNR and NEdT requirements. Most spectral bands are meeting the dynamic range requirements, and most dual gain bands also meet requirements. Reflective solar band (RSB) gains and SNRs were shown. Measured SNR for all VIIRS RSBs meet specified requirements at typical radiance (Ltyp). Thermal emissive band (TEB) gains and NEdTs were shown. A few detectors failed SNR/NEdT in Run 3. A summary of the dynamic range compliance was shown. Band M8 did not meet the dynamic range requirement. There is concern about the impact of the Solar Instrument Suite (SIS) 100 stability on radiometric calibration. Better characterization of the SIS monitor is needed. The thermal vacuum test will provide final results. The RSB and TEB RVS characterizations meet requirements. The SIS monitor approach was not satisfactory.

The purpose of the FU1 VIIRS polarization insensitivity test for VisNIR bands is to examine the sensitivity of the sensor to polarized light. The derived polarization factors from all tests satisfy the VIIRS specification for the polarization factor.

The radiance from Earth and/or clouds outside the sensor's field of view (FOV) will be the main source of stray light. The functional performance characterization test, FP-12, simulated stray light sources comparable to on-orbit conditions. Many M bands do not meet the original requirements. The evaluation and approval of waiver request for new requirements is underway.

For near field response, the functional performance characterization test, FP-14, evaluated the ability of the sensor to measure the radiance from a region of the Earth that differs from adjacent scenes. The preliminary results show that bands M4, 12, 13, and 16 are non-compliant. Ghosting signals were found in the TEB. A waiver has been requested. The root cause of ghosting is known. The Northrop Grumman Space Technology's (NGST) sensor data record (SDR) results suggest no substantial impact in the emissive band SDR for SST.

Spatial performance consists of four tests. All bands align well, including the I and M bands. The instrument meets specifications. The measurements agree

with the EDU and are also within specification. Changes due to on-orbit conditions (gravity release, temperatures) are expected.

Eric Vermote [University of Maryland] discussed the use of MODIS and Polarization and Directionality of the Earth's Reflectances (POLDER) data to develop a generalized approach for correction of the bidirectional reflectance distribution function (BRDF) effects. The purpose of the research is to account for directional effects in the Advanced Very High Resolution Radiometer (AVHRR) and MODIS long-term record. The presentation showed that directional effects on reflectance time-series data can be accounted for with simple linear models. Data from the POLDER instrument flying on the Advanced Earth Observation Satellite (ADEOS) have been used to define the approach towards a BRDF. Vermote tested this approach on daily MODIS surface reflectance data at the climate modeling grid (CMG) scale and developed a new approach to BRDF inversion. This new approach allows the reflectance to vary slowly within the time interval, bringing improvements over classical inversion with a greater reduction in noise. A further decrease in noise was obtained by allowing the volume and roughness BRDF parameters to vary as a function of the normalized difference vegetation index (NDVI). NDVI values after the new BRDF correction were improved by a factor of two for most land-cover types. The correction could be applied to other time-series datasets, and the volume and roughness coefficients could be used for other applications. Vermote intends to use the approach in the long-term data record (LTDR) project to correct MODIS and AVHRR surface reflectance time series for the BRDF effect.

Michael King [University of Colorado/Laboratory for Atmospheric and Space Physics (LASP)] provided a summary of the breakout sessions held by the atmosphere team. Fourteen science presentations were given. New uses of MODIS data are increasing with other data sources like CALIPSO. The atmosphere group discussed differences between MODIS and VIIRS. The group also discussed needs and plans for *C6*. A highly popular application of MODIS data at operational meteorological centers worldwide is the use of polar vector wind data. MODIS makes multiple passes of the polar regions, and can provide frequent vector wind data. VIIRS won't have the capability to monitor vector winds. Another science deficiency is cloud-top pressures, which are highly ambiguous compared to MODIS. In that regard, the VIIRS capability is similar to AVHRR and a step backwards from MODIS. The Geostationary Operational Environmental Satellites (GOES-R) will be comparable to MODIS, but geosynchronous. These two omissions have science consequences. The team compiled a wish list for *C6*. *C5.1* reprocessing will start soon to update both Terra and Aqua with *Deep Blue* and cloud-top properties.

Chris Justice reported the activities of the land team during its breakout sessions. NPP VIIRS issues were discussed in the land group. The current focus of the team is on land EDR evaluation and NASA Earth Science Data Record (ESDR) generation. Plans are being made for algorithm testing and product validation. Justice highlighted recommendations for improvements to the follow-on VIIRS instrument, including the capacity for fire characterization. The entire science team should prioritize the recommended changes across disciplines and work with NASA management to secure the necessary improvements in VIIRS. These improvements will extend the MODIS data record.

A higher resolution land-water mask continues to be needed for MODIS and VIIRS. The land team discussed the process for developing and reviewing algorithm theoretical basis documents (ATBD) for new standard products. *C5* reprocessing is now complete, and principal investigator (PI) web sites need to be updated with *C5* user guides and validation status. Some changes have resulted from the most recent EOS recompete. Vegetation cover change is a discontinued product. The vegetation index (VI) and leaf area index (LAI) products will not be part of a *C6* reprocessing. Issues of *C5*/*C6* dependencies have yet to be resolved. The *C5* products are now being used for product inter-comparison. In this regard, and for land product validation, international partnerships are important. A comparison between MODIS, the Atmospheric Infrared Sounder (AIRS), and ASTER revealed errors in the *Version 5* Land Surface Temperature product. This version will now be updated. The community needs time to evaluate *C5* and what is being proposed for *C6*.

Land science results presented during the meeting included the green-up of the Amazon forest in the dry season. This shows the resilience of the rainforest to climate anomalies and drought and the correlation between MODIS net primary production (NPP) and inverted carbon dioxide interannual growth rates. A new dataset for MODIS evapotranspiration is planned for release and a new land measurement portal has been developed. The portal highlights moderate resolution data and products for land studies. It also includes information about the major land product suites, products, international coordination, and upcoming meetings.

Bob Evans provided a summary of the ocean team's breakout sessions, including a number of science presentations that covered a wide scope of work. Many of these will not be possible with VIIRS. New science includes adaptation or extension of aerosol models used in ocean color processing to improve data from coastal areas. The range of ocean color data is being extended by including models. The process relies on the range of channels available on MODIS. The team discussed how harmful algal blooms are investigated. A new product

will provide the capability to record FLH. Calibration and validation were discussed in the breakout. The ocean group defined ocean biogeochemistry issues and recommendations for VIIRS. In the near term, the team would like to improve VIIRS sensor performance and attributes, specifically optical crosstalk and characterization data quality. On-board calibration with on-orbit maneuvers is needed. The thermal vacuum test data is necessary to access other recommendations. For FU2, the ocean color group would like a remanufactured IFA, dual gains in band M6, SST and fires bands, and two times higher SNRs in bands M8 and M10. In the longer term, the team wants to add additional bands: FLH bands, an ultraviolet (UV) band, and a 510 nm band for turbid water chlorophyll. The team also wants to split the 4 μm band into 3.95 μm and 4.05 μm bands. Processing and reprocessing will be needed with current generation algorithms. The team is gearing up for new science thrusts for the ocean geochemistry program. New missions and international sensors hope to focus on coastal regimes, science theme refinement, habitats, and multi-disciplinary science.

Paula Bontempi discussed the overlapping requirements for VIIRS-2 that are emerging from the science team disciplines. She asked the science team where they would encounter gaps in time series data records. The measurement streams will continue to evolve through the MODIS science team. The EOS recompete will occur in 2009 or 2010. The idea in the mission-to-measurements theory is to ensure a seamless time series. One success of the MODIS science team is the blending of science teams between instruments and disciplines. Bontempi asked the group if they wanted to move towards Terra and Aqua science team meetings, with the next interdisciplinary science team meeting to be held in six months. The evolution of efforts from missions-to-measurements will have to incorporate NPOESS and other future missions. Systematic observations from current sensors are key to climate and Earth system research. The science team needs to look at gaps in systematic observations versus new observations needed for possible new missions.

Algorithms should be reviewed to plan for new or alternative EOS algorithms. For current products, principle investigators should provide a justification for the utility of each algorithm and plan for the transition to core production. Data product documentation and regular reviews are needed. New algorithms or data products would follow a similar pattern for review.

The Headquarters mission extension senior review is coming up in 2009. There has been tremendous progress in science, particularly in interdisciplinary and intersensor science. The DAACs are reaching wide communities. Each discipline should coordinate algorithm reviews by teleconference.

Diane Wickland was impressed with the progress in science and data distribution. The community is acquiring knowledge about the capabilities of VIIRS and its potential improvements. A plan is needed for how to bring those issues forward. It is helpful for the science team to notify Headquarters about what is needed for VIIRS. Wickland recommended that the broad user community, including modeling and application users, work with the science team on the issue of ESDRs.

James Butler [NASA GSFC] was impressed with the high quality of data that MODIS produces. On the second day of the meeting, the VIIRS instrument was discussed. The NPP Instrument Characterization Support Team (NICST) has processed a lot of data on VIIRS. A critical time for the VIIRS instrument is next with the pre-thermal vacuum and thermal vacuum testing. Butler suggested a tighter relationship between NICST and the science team to discuss the impact of the tests results on science. Input about ways to enable Earth science through recommended improvements to VIIRS FU2 should be emailed to Jim Gleason. An NPP science team meeting is tentatively scheduled for March 2009.

Vince Salomonson concluded the meeting by stating that MODIS has matured. *C6* will be completed with input from the science team. As already noted, the NASA Headquarters senior review of extended missions is approaching. Salomonson requested that information for the review be sent to him. A multi-sensor or multidisciplinary meeting may be held towards the end of the year or in 2009. ■

in the news

NASA Data Show Some African Drought Linked to Warmer Indian Ocean

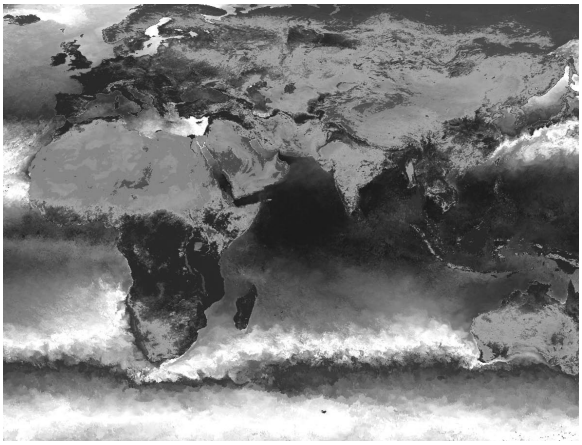
Kathryn Hansen, NASA Earth Science News Team, khansen@sesda2.com

A new study, co-funded by NASA, has identified a link between a warming Indian Ocean and less rainfall in eastern and southern Africa. Computer models and observations show a decline in rainfall, with implications for the region's food security.

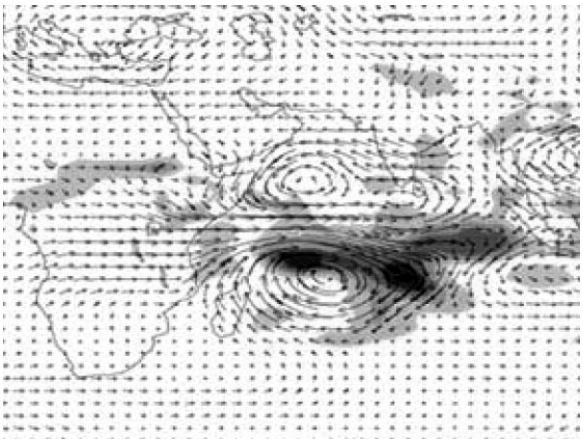
Rainfall in eastern Africa during the rainy season, which runs from March through May, has declined about 15% since the 1980s, according to records from ground stations and satellites. Results of statistical analyses published recently in proceedings of the National Academy of Sciences indicate that this decline is due to irregularities in the transport of moisture between the ocean and land, brought about by rising temperatures in the Indian Ocean, according to research published recently in *Proceedings of the National Academy of Sciences*. This interdisciplinary study was organized to support the U.S. Agency for International Development's Famine Early Warning Systems Network.

"The last 10 to 15 years have seen particularly dangerous declines in rainfall in sensitive ecosystems in East Africa, such as Somalia and eastern Ethiopia," said **Molly Brown** of NASA's Goddard Space Flight Center, a co-author of the study. "We wanted to know if the trend would continue or if it would start getting wetter."

To find out, the team analyzed historical seasonal rainfall data over the Indian Ocean and the eastern seaboard of Africa from 1950 to 2005. The NASA Global Precipitation Climatology Project's rainfall dataset provided a series of data covering both the land and the oceans. They found that declines in rainfall in Ethiopia, Kenya, Tanzania, Zambia, Malawi, and Zimbabwe were linked to increases in rainfall over the ocean.



Sea surface temperatures and land vegetation over the Indian Ocean are seen below in a visualization created with data from 1994 to 2005 from the Pathfinder satellite dataset. To view this image in color please go to: *www.nasa.gov/topics/earth/features/indian_ocean_warm.html.* **Image Credit:** NASA.



Arrows show the simulated movement of moisture, and dark to light shading indicate variations in cool to warm sea-surface temperatures. To view this image in color, please go to: *www.nasa.gov/topics/earth/features/indian_ocean_warm.html.* **Image credit:** Mathew Barlow/ University of Massachusetts.

The team used computer models that describe the atmosphere and historical climate data to identify and validate the source of this link. Lead author **Chris Funk** of the University of California, Santa Barbara, and colleagues showed that the movement of moisture onshore was disrupted by increased rainfall over the ocean.

Funk and colleagues used a computer model from the National Center for Atmospheric Research to confirm their findings. **The combination of evidence from models and historical data strongly suggest that human-caused warming of the Indian Ocean leads to an increase of rainfall over the ocean, which in turn adds energy to the atmosphere.** Models showed that the added energy could indeed create a weather pattern that reduces the flow of moisture onshore and brings dry air down over the African continents resulting in reduced rainfall.

Next, the team investigated whether or not the decline in rainfall over eastern Africa would continue. Under guidance from researchers at U.S. Geological Survey, which co-funded the study, the team looked at 11 climate models to simulate rainfall changes in the future. Ten of the 11 models agreed that through 2050, rainfall over the Indian Ocean would continue to increase—depriving Africa's eastern seaboard of rainfall.

"We can be quite certain that the decline in rainfall has been substantial and will continue to be," Funk said. "This 15% decrease every 20-25 years is likely to continue."

The trend toward dryer rainy seasons in eastern and southern Africa directly impacts agricultural productivity. To evaluate how potential future rainfall scenarios and shifts in agriculture could affect undernourishment, the team came up with a *food-balance indicator* model. The model considers factors such as growing-season rainfall, fertilizer, seed use, crop area, and population to estimate the number of undernourished people a region can anticipate.

Continuing along a *business as usual* scenario—with current trends in declining rainfall and agricultural capacity continuing as they are currently to 2030, the team found that the number of undernourished people will increase by more than 50% in eastern Africa.

Still, the food-balance indicator also showed that in the face of a continuation of the current downward trend in rainfall, even modest increases in agricultural capacity could reduce the number of undernourished people by 40%.

"A strong commitment to agricultural development by both African nations and the international community could lead fairly quickly to a more food-secure Africa," Funk said. ■

Experience NASA Science at the 2008 Fall AGU

Please join us at the NASA booth (#2321) during this year's Fall Meeting of the American Geophysical Union (AGU), where we will offer a wide variety of science presentations, interactive demonstrations, and tutorials for a variety of data tools and services. This year's program begins on **Tuesday, December 16** and will continue through **Thursday, December 18, 2008**.

Science presentations will focus on a diverse range of research topics, science disciplines, and programs within NASA's Science Mission Directorate. Interactive data-oriented demonstrations will include sessions on data accessibility and search-and-order capabilities, and will feature selected data visualization, data conversion, and other data manipulation tools.

A daily agenda will be posted on the Earth Observing System Project Science Office (EOSPSO) web site—*eos.nasa.gov*—in early December.

We look forward to seeing you in San Francisco!

in the news

Ocean Surface Topography Measurements a Boon for Extreme Event Forecasts, Warnings

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

For humans in the path of destructive hurricanes and tsunamis, an accurate warning of the pending event is critical for damage control and survival. Such warnings, however, require a solid base of scientific observations, and a new satellite is ready for the job.

The Ocean Surface Topography Mission (OSTM)/ Jason 2 adds to the number of eyes in the sky measuring sea-surface and wave heights across Earth's oceans. The increased coverage will help researchers improve current models for practical use in predicting hurricane intensity, while providing valuable data that can be used to improve tsunami warning models.

"When it comes to predicting hurricane intensity, the curve in the last 40 years has been somewhat flat, with little advance in how to reduce error in predicted intensity," said **Gustavo Goni**, of the National Oceanic and Atmospheric Administration (NOAA) in Miami. Maps of sea-surface height created from satellites, however, could help change the curve.

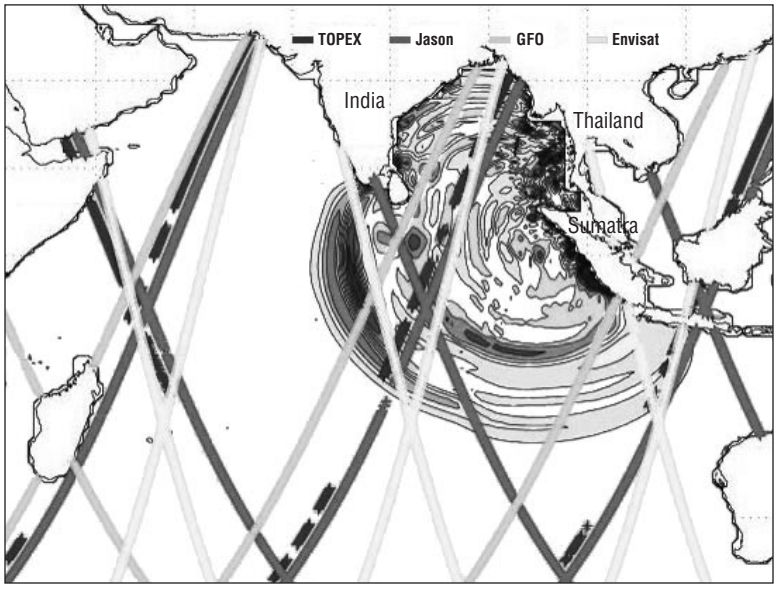
Satellites that measure sea surface height have been running operationally nonstop since November 1992. But in order to identify all the features that could be responsible for intensification of tropical cyclones all over Earth two of these satellites have to be in orbit at the same time. The OSTM/Jason 2 mission will help make the additional coverage possible. (OSTM/Jason 2 joins Jason 1 which has been in orbit since 2001.)

NASA, university, and NOAA investigators, including Goni, work to transform sea surface height information obtained from satellites, such as OSTM/Jason 2, into maps of ocean heat content. Forecasters can use the maps to develop models that predict how hurricanes will strengthen.

Determining heat content from sea-surface height is possible because warm water is less dense and hence sits higher than cooler water. In some regions, such as inside and outside the Gulf Stream current, the temperature differences result in more than a 3-ft (1-m) difference in sea-surface height. Goni and colleagues use this established concept to estimate from sea-level variations how much heat is stored in the upper ocean in areas where hurricanes typically develop and intensify.

While sea-surface height may not necessarily be the most significant parameter for hurricane intensity forecasts, researchers now know that if sea-surface height is accounted for in current forecast models, errors in forecasts for the most intense storms are reduced. For weak storms, the reduction in error is not very significant. However, for storms in the strongest Category 5 range, the heat content in the upper ocean derived from sea-surface height becomes increasingly important. "This is a good thing, because these are the storms that produce the most damage," Goni said.

"OSTM/Jason 2 will help us to keep the necessary coverage that we need to identify ocean features that can be linked to tropical cyclone intensification, because with only one satellite we may miss some of them," Goni said.



Satellites passed over the Indian Ocean tsunami of December 2004. Two of those satellites—Jason 1 and TOPEX/Poseidon—were equipped with altimeters that, for the first time, measured the height of a tsunami in the open ocean. To view this image in color please go to: *www.nasa.gov/mission_pages/ostm/news/ostmf-20080716.html.* **Image credit:** NASA/JPL.

Upper ocean heat content derived from sea surface height is now used in operational and experimental forecast models in all seven ocean basins where tropical cyclones exist.

In December 2004, two satellites happened to be in the right place at the right time, capturing the first space-based look at a major tsunami in the open ocean—see figure on previous page. Within two hours of a magnitude 9 earthquake in the Indian Ocean southwest of Sumatra, the Jason 1 and TOPEX/Poseidon satellites fortuitously passed over the path of the resulting tsunami as it traveled across the ocean. It measured the leading wave, traveling hundreds of miles per hour in the open ocean, at about 1.6 feet (0.5 meters) tall.

Wave height measurements like those of the Indian Ocean tsunami do not provide an early warning because the information is not relayed to ground stations in real time. That's the job of early warning systems operated by NOAA and other global organizations that currently employ a network of open-ocean buoys and coastal tide gauges. Sea-surface height measurements of tsunamis can, however, help scientists test and improve ground-based models used for early warning. One such system developed at NASA's Jet Propulsion Laboratory (JPL), and undergoing tests at NOAA's Pacific Tsunami Warning Center, could become operational within about three years.

Most tsunamis are caused by undersea earthquakes. Using the JPL-developed system, when seismometers first identify and locate a large earthquake, scientists can use GPS measurements to search around the earthquake's source to see if land has shifted, potentially spurring a tsunami. Scientists can then immediately compile the earthquake's size, location, and land movement into a computer program that generates a model tsunami to determine the risk of a dangerous wave. After the wave passes, scientists can search through wave height data from satellites and verify what the model predicted.

"Satellite data play the crucial role of verifying tsunami models by testing real tsunami events," said JPL research scientist **Tony Song**. "If an earthquake generates a tsunami, does the satellite data match observations on the ground and model predictions?"

"One of the unique pieces of satellite observations is the large-scale perspective," said JPL research scientist **Philip Callahan**. Tsunamis can have waves more than 100 mi (161 km) long. Such a wave would likely go unnoticed by an observer in a boat on the ocean's surface. But satellite altimeters like OSTM/Jason 2 can see this very long wave and measure its height to an accuracy of about 1 in (2.5 cm).

Scientists' ability to test tsunami warning models will be aided by OSTM/Jason 2. With the TOPEX/Poseidon mission now ended, the currently orbiting Jason 1 has been joined by and will eventually be replaced by OSTM/Jason 2. This will help ensure that future tsunamis will also be observed by satellites as well as by buoys and tide gauges.

"The biggest value in satellite measurements of sea-surface height is not in direct warning capability, but in improving models so when an earthquake is detected, you can make reliable predictions and reduce damage to property and people," Callahan said.

For more information on OSTM/Jason 2, visit: *www.nasa.gov/ostm*.

For more information on JPL's climate change research programs, visit: *climate.jpl.nasa.gov*. ■

EOS Scientists in the News

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

Ready to Respond, June 9, 2008; *Aviation Week & Space Technology*. **Chris Naftel** (NASA DFRC) explains the long-range capabilities of NASA's Global Hawks for Earth science research.

Will There Be More Pollution in the Future?, June 24, 2008; *Earth & Sky Radio*. **Ralph Kahn** (NASA GSFC) believes the amount of air pollution in the future will depend on the increasing energy demand of developing nations, as well as developments that lead to fuels that produce less pollution.

North Pole May Be Ice-Free in Summer, **Expert Says**, June 28, 2008; *Associated Press*. **Jay Zwally** (NASA GSFC) weighs in on the chance that the North Pole will be ice-free this summer, saying he thinks the chance is just less than 50-50, based on satellite images from early in 2008 that show the North Pole's ice is thinner than has been seen in five years of available satellite images.

Greenland Ice Sheet Slams the Brakes On, July 3, 2008; *New Scientist*. Some research suggests that the lubricating effect of meltwater on the western edge of Greenland's ice sheet is negligible and doesn't contribute much to ice loss, but **Jay Zwally** (NASA GSFC) notes that it's important to focus on the last five years, when the most rapid melting at the edges of the ice sheet started, and says the eastern edge of the ice sheet has lost between 3–5% more ice due to the lubricating effect of meltwater.

Fires Could Go 'Pyro,' July 4, 2008; *Canwest News Service*. **Jim Crawford** (NASA HQ) and **Daniel Jacob** (Harvard University) were among 120 scientists in Cold Lake, Alberta, tracking forest fire smoke plumes from two NASA research planes as part of a mission to probe the role of air pollution on the Arctic.

NASA Team Lands in Yellowknife to Study Forest Fire Smoke, July 7, 2008; *CBC News*. In June and July, about a dozen scientists including **Chris Hostetler** (NASA Langley) worked in Yellowknife, Northwest Territories, where they used lasers, airplanes, and balloons as tools in a mission to collect data on smoke from wildfires and other pollution in the atmosphere.

JPL Climatologist Offers Tips to Beat the Summer Heat, July 10, 2008, *The San Marino Tribun*e. Southern Californians saw heat waves early in 2008, starting in June, and the heat waves could continue into September, which is typically the hottest month, according to **Bill Patzert** (NASA JPL), who also gave some ideas about what residents can do to stay cool.

NASA Drone's Sensors Help Battle California Wildfires, July 15, 2008; *EE Times*. The California Department of Forestry and Fire Protection called upon scientists—including **Vincent Ambrosia** (NASA Ames)— to deploy NASA's unmanned aerial vehicle, which has temperature sensors that help firefighters, blinded by smoke, to locate hotspots and distinguish between hot ash and active flames.

Governor Praises NASA's 'Superstar' in Fire Effort, July 15, 2008; *San Francisco Chronicle*. Gov. Arnold Schwarzenegger credited an unmanned NASA aircraft with helping save the Sierra foothills town of Paradise from a wildfire; **Steve Hipskind** (NASA Ames) likens the infrared imaging system on the plane to taking an MRI of the fire.

Audios La Niña, July 25, 2008; *KPCC 89.3 (Southern California)*. **Bill Patzert** (NASA JPL) describes how La Niña led to a dry winter last year with rainfall at about 4 in below normal in Orange County, CA, but La Niña has faded away this year and forecasters are waiting to see if the region experiences a wet winter and fall.

Is Climate Change Causing an Upsurge in U.S. Tornadoes?, July 30, 2008; *New Scientist*. The early and intense tornado season in 2008 coincided with warm temperatures, but **Anthony Del Genio** (NASA GISS) warned against concluding that the storms imply climate change.

Climate Change: The Next Ten Years, August 13, 2008; *New Scientist*. **Gavin Schmidt** (NASA GISS) explains why it's difficult to forecast the climate over the next ten years, in the window beyond the short, few-day outlook included in weather forecasts and before the more distant predictions of climate change.

Aerosols' Link with Climate Discovered, August 14, 2008; *UPI NewsTrack*. **Lorraine Remer** (NASA GSFC) and colleagues used a theoretical model to identify how aerosols from human activity, like the particles from burning of vegetation and forests, lead to less cloud cover over the Amazon and ultimately affect climate.

Making Climate Forecasting More Useful, August 20, 2008; *The New York Times*. When posed with the question about whether or not money will make climate forecasting more useful to society, **Gavin Schmidt** (NASA GISS) replied that short-term changes over small land areas are not described by climate models, rendering changes on such small scales unpredictable; benefits, however, could come from climate simulation projects, such as pollution's impact on health, as well as from more resources invested in finding out what communities need to know.

Interested in getting your research out to the general public, educators, and the scientific community? *Please contact Kathryn Hansen on NASA's Earth Science News Team at khansen@sesda2.com and let her know of your upcoming journal articles, new satellite images, or conference presentations that you think the average person would be interested in learning about.* ■

When the Geostationary Operational Environmental Satellite (GOES) captured this view of the atmosphere at 1:45 p.m. Eastern Daylight Time on September 3, 2008, four current or former tropical cyclones were lined up across the Atlantic, and one had developed in the Eastern Pacific. GOES' view of the clouds is overlaid on the NASA Blue Marble.

Near the African coast, Tropical Storm Josephine was slowly losing power under the influence of dry air and contrary winds. The storm is little more than a cluster of clouds in this image.

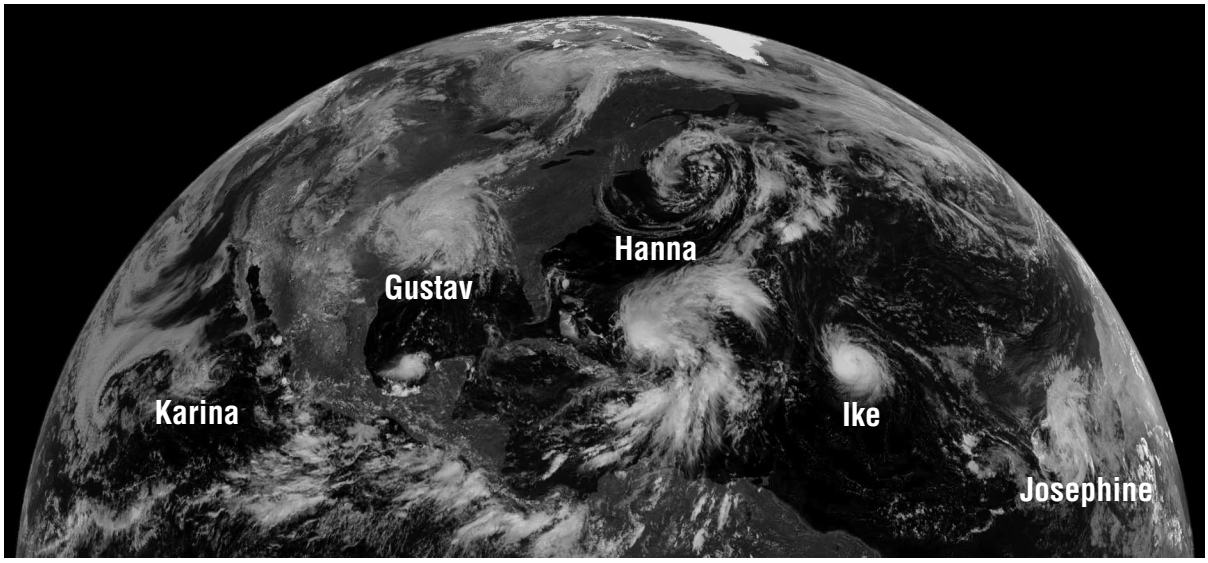
Hurricane Ike is the most well-established storm in the image. The tight circle of bright clouds was an intensifying tropical storm that within a single day became a powerful *Category 4* hurricane—the fifth of the Atlantic season. Eventually Hurricane Ike's track moved westward passing over the Turks and Caicos Islands and Cuba, through the Gulf of Mexico, and made U.S. landfall at Galveston, TX on September 13.

Next in line is Tropical Storm Hanna. Formerly a hurricane, Hanna weakened into a tropical storm on September 2. The sprawling storm was intensifying as it moved northwest over the Bahamas. Later, Hanna's track turned northward and made landfall near the South Carolina-North Carolina border on September 6.

The final two storms are tropical depressions. Gustav sits nearly stationary over Arkansas. Despite having been over land for two days, the storm maintains its circular shape. It was drenching the Mississippi Valley with flood-inducing rain.

More benign is Tropical Depression Karina, west of Baja, CA. The storm formed on September 2 and was quickly degenerating by September 3.

For more information and to view this image in color visit: *earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=18140*
Credit: NASA's Earth Observatory



NASA Science Mission Directorate – Science Education Update

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NEW NASA 'FIRE & SMOKE' WEB PAGE SHOWS LATEST FIRE VIEWS, RESEARCH

NASA satellites, aircraft, and research know-how have created numerous cutting-edge tools to help firefighters battle wildfires. These tools also have helped scientists understand the impact of fires and smoke on Earth's climate and ecosystems. Now, a new NASA website brings to the public and journalists the latest information about this ongoing effort. Access the site at: *www.nasa.gov/fires.*

LANDSAT DATA IN NEW UNEP ATLAS OF AFRICA'S ENVIRONMENTAL CHANGE

This Atlas, compiled on behalf of the ministers by the United Nations Environment Programme (UNEP), underlines how development choices, population growth, climate change, and, in some cases, conflicts are shaping and impacting the natural and nature-based assets of Africa. Taking advantage of the latest space technology and Earth observation science, including the 36-year legacy of the U.S. Landsat satellite program, the Atlas serves to demonstrate the potential of satellite imagery data in monitoring ecosystems and natural resources dynamics. For more information on the UNEP Atlas, visit: *landsat.gsfc.nasa.gov/news/news-archive/news_0152.html.* To view and access Landsat data, visit: *landsat.gsfc.nasa.gov/data/where.html.*

USING RADIOSONDE DATA FROM A WEATHER BALLOON LAUNCH

A new lesson plan designed for grades 7-12 is now available through MY NASA DATA. The data (air temperature, dew point, and air pressure) was collected during a July 2005 balloon launch at NASA Langley Research Center. Students use the data to analyze weather parameters and distinguish characteristics of the lower atmosphere. It is available at: *mynasadata.larc.nasa.gov/preview_lesson.php?&passid=34*.

NASA SPONSORS ODYSSEY OF THE MIND

For the ninth time, NASA's Earth Observing System Project Science Office is sponsoring an Odyssey of the Mind Long-Term Problem—Earth Trek—that requires teams to design and build a small vehicle that will visit four locations. The locations will be different places within one or more team-determined environments. Each time the vehicle leaves a location it will look different in appearance, and after leaving one of the locations it will appear to be a group of vehicles that are traveling together. The team's performance will incorporate the visits to the locations, the environments, and the changes in appearance of the vehicle. Odyssey of the Mind is an international educational program that provides creative problem-solving opportunities for students from kindergarten through college. For more information, including team registration and practice problems, visit: *www.odysseyofthemind.com/*.

Free Global Climate Change Course for Informal Educators

Global Climate Change and Informal Earth System Science is an online, 10-week graduate course designed to provide professional development for the informal Earth system science education community. There are two modules, *Global Climate Change*, and *Earth System Science in Your Backyard*. This course will be asynchronous and conducted entirely online. Participants' will receive a mini-grant for $500 for each staff person (maximim of two per institution) who successfully completes the course, to be used toward implementation of his/her project. To enroll see *www.oneonta.edu/academics/conted/NDG.htm.* Register at *webservices.oneonta.edu/*. Contact Carlyn Buckler for further information: *csb36@cornell.edu*. This course is part of the NASA and NSF-funded Earth System Science Education Alliance (*esseacourses.strategies.org*).

NASA ASTRONAUT READY TO ANSWER YOUR QUESTIONS FROM SPACE

Flying 220 miles above the Earth aboard the International Space Station, NASA astronaut Greg Chamitoff is ready to take your questions. Chamitoff is a flight engineer for the *Expedition 17* mission. The public can now submit inquiries to Chamitoff and get answers direct from space on NASA's Web site. To submit a question, visit: *www.nasa.gov/ask*. Check back periodically for the transcript and audio clips of the astronaut's answers. ■

EOS Science Calendar

2008

October 15-17
HDF & HDF-EOS Workshop XII, Denver, CO. URL: *www.hdfeos.org/workshops/ws12/workshop_twelve.php*

October 27-30
Aura Science Team Meeting, Columbia, MD. URL: *aura.gsfc.nasa.gov/*

October 27-31
CERES/GERB Science Team Meeting, NASA GISS, New York, NY. URL: *science.larc.nasa.gov/ceres/meetings.html*

November 10-12
Ocean Surface Topgraphy Science Team Meeting, Palais des Congrès Acropolis, Nice,France URL: *www.ostst-godae-2008.com/frontoffice/index.php?id_lang=2&id_rub=90* Contact: Lee-Lueng Fu, *llf@jpl.nasa.gov*

December 8-12
ASTER Science Team Meeting, Pasadena, CA. Contact: Mike Abrams, *Michael.J.Abrams@jpl.nasa.gov*

December 12-13
GRACE Science Team Meeting, San Francisco, CA. URL: *www.csr.utexas.edu/grace/GSTM/*

2009

January 6-8
Landsat Science Team Meeting, Fort Collins, CO. Contact: Thomas Loveland *loveland@usgs.gov*

January 12-15
LCLUC Science Team Meeting, Khon Kaen, Thailand. URL: *lcluc.hq.nasa.gov*

Global Change Calendar

2008

November 12-14
International DORIS Service (IDS) Workshop, Palais des Congrès Acropolis, Nice, France. URL: *www.ostst-godae-2008.com/frontoffice/index.php?id_lang=2&id_rub=92*, Contact: Gilles Tavernier, g*illes.tavernier@cnes.fr*

November 12-15
Final Symposium of the Global Ocean Data Assimilation Experiment, Palais des Congrès Acropolis, Nice, France. URL: *www.ostst-godae-2008.com/frontoffice/index.php?id_lang=2&id_rub=91*, Contact: Kirsten Wilmer-Becker, *kirsten.wilmer-becker@metoffice.gov.uk*

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

December 2-6
Pan Oceanic Remote Sensing Conference, Guangzhou, China. URL: *http://ledweb.scsio.ac.cn/porsec2008*

December 5-13
The Fourth International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 2008) URL: *www.cisse2008online.org*

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

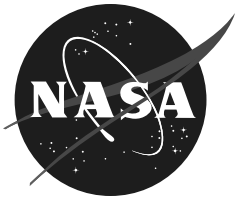
2009

January 11-15
89th Annual Meeting of the American Meteorological Society (AMS), Phoenix, AZ. URL: *www.ametsoc.org/MEET/annual/index.html*

April 26-30
7th International Science Conference on the Human Dimensions of Global Environmental Change (Open Meeting), Bonn, Germany. Contact: *openmeeting@ihdp.unu.edu*; URL: *www.ihdp.org/*

May 4-8
41st International Liege Colloquium on Ocean Dynamics, Liege, Belgium. URL: *modb.oce.ulg.ac.be/colloquium/*

May 4-8
33rd International Symposium on Remote Sensing of Environment Stresa, Lake Maggiore, Italy. URL: *isrse-33.jrc.ec.europa.eu/index.php?page=home*



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