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EDITOR'S CORNER

Michael King
EOS Senior Project Scientist

Following eleven weeks of on-orbit checkout and verification and a series of eight orbital ascent maneuvers, the Terra spacecraft reached its final orbit on February 24. The final orbit is a sunsynchronous polar orbit with an equator crossing time of 10:45 AM. As such, it is on the same worldwide Reference System ground track and just 40 minutes behind Landsat 7. With the ground system providing excellent support for spacecraft command and control, the data are now beginning to flow, and the preliminary analysis of observations from the five instruments onboard the spacecraft is exciting. The first public release of data from Terra will likely occur around mid-April.

The Office of Earth Science has now finalized the selection of proposals arising from the NASA Research Announcement for investigations under the EOS Interdisciplinary Science Program that was released in May 1999. NASA received 170 proposals in response to this announcement, 59 of which were approved. Eleven of these proposals are considered continuations of the initial set of IDS investigations, and the others are either new to the EOS program or renewals of more-recent IDS investigations. Of these investigations, 36 are from the University community, 19 from US government laboratories, and 4 from private industry or foreign institutions. Details of the selections can be found at www.earth.nasa.gov/nra/archive/selection_results.html. The final selection results can be summarized as follows:

Land-Biosphere Interactions	27
Atmosphere	21
Oceans and Ice	11

The AIRS/AMSU-A/HSB, AMSR-E, SAGE III, ACRIM III, and Data Assimilation science teams have developed Algorithm Theoretical Basis Documents (ATBDs) that are currently being reviewed by the international scientific community. Following these written evaluations, an oral portion of this review will be conducted on March 14-15 by a visiting committee

chaired by Prof. Steve Ackerman of the University of Wisconsin. A total of 23 ATBDs will be reviewed. These documents, developed for each data product, consist of a detailed physical and mathematical description of the algorithm, variance or uncertainty estimates, and practical considerations, such as calibration and validation, exception handling, quality assessments and diagnostics. These documents will be posted on the World Wide Web following revisions that result from the written reviews as well as panel report recommendations.

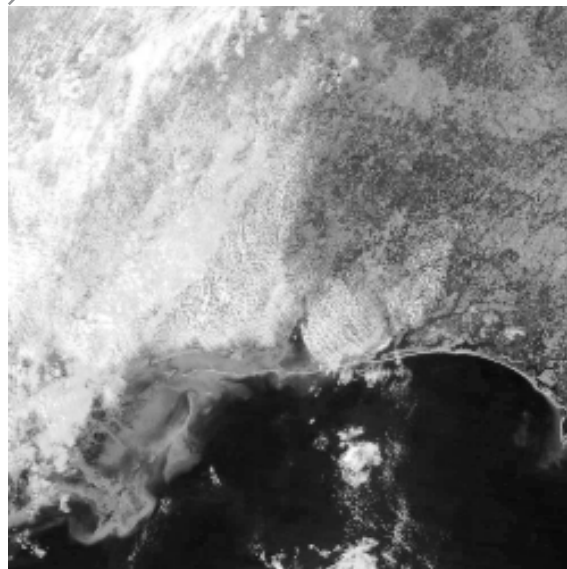
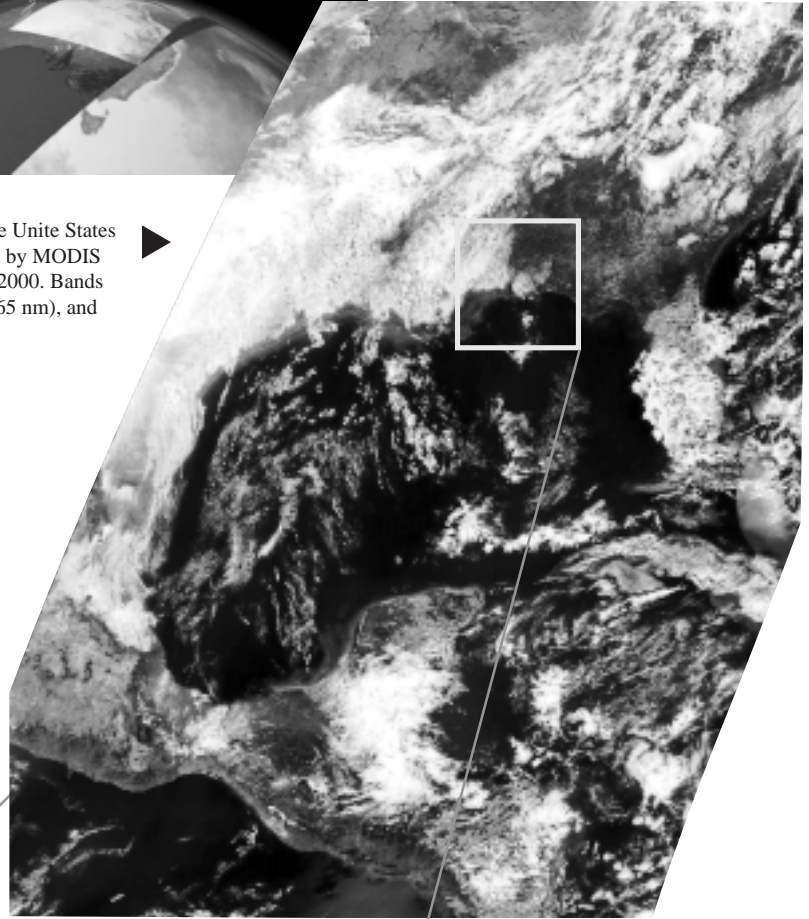
The next EOS Investigators Working Group meeting will take place April 11-13 in Tucson, Arizona at the Hilton Tucson East Hotel. The main themes of the meeting will be early science results from Terra, and there will be topical sessions on ocean, land, and atmospheric science findings from recent missions such as Landsat 7, and QuikScat. EOS validation activities, Regional Earth Science Applications Centers (RESACs), Earth Science Information Partners, and both European and Japanese Earth observation mission status overviews will also be presented. Logistics, travel information, and a draft agenda can be found at eosps0.gsfc.nasa.gov/eos_homepage/logreg.html.

Finally, I am happy to report that Dr. Waleed Abdalati has agreed to serve as Deputy ICESat Project Scientist, helping Dr. Jay Zwally, Project Scientist, in preparing the ICESat mission and its GLAS instrument for flight in July 2001.



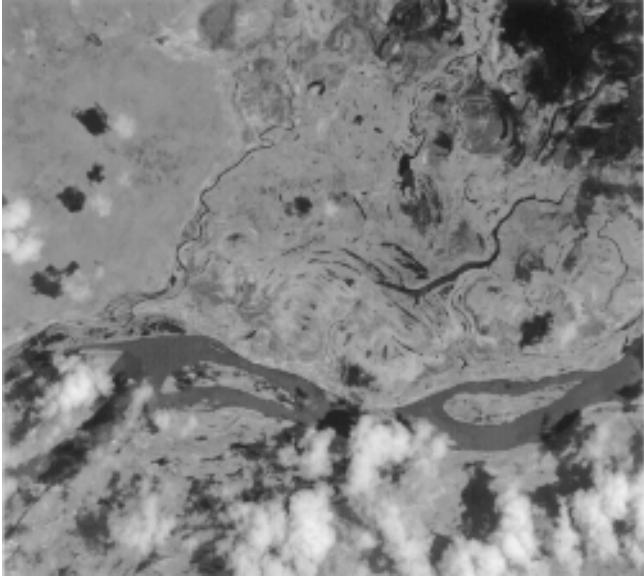
First image of the United States east coast sensed by MODIS on February 24, 2000. Bands 1 (670 nm), 4 (565 nm), and 3 (479 nm).

MODIS First Image

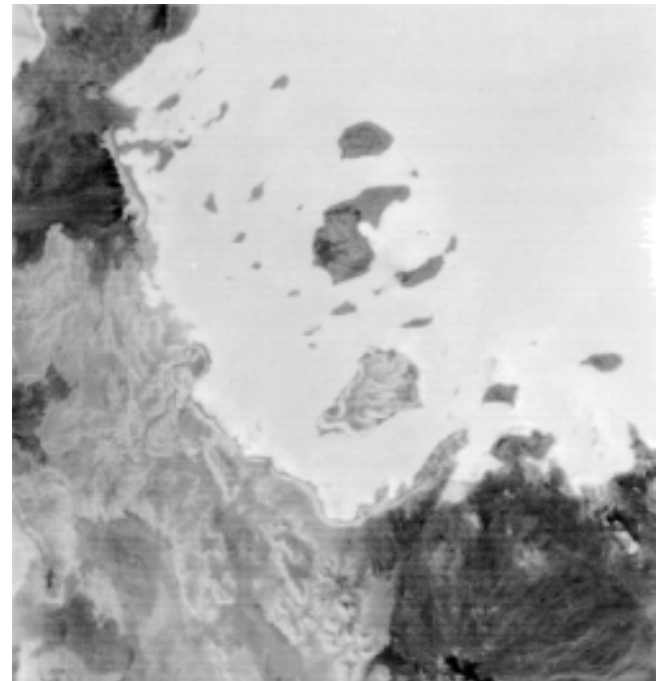
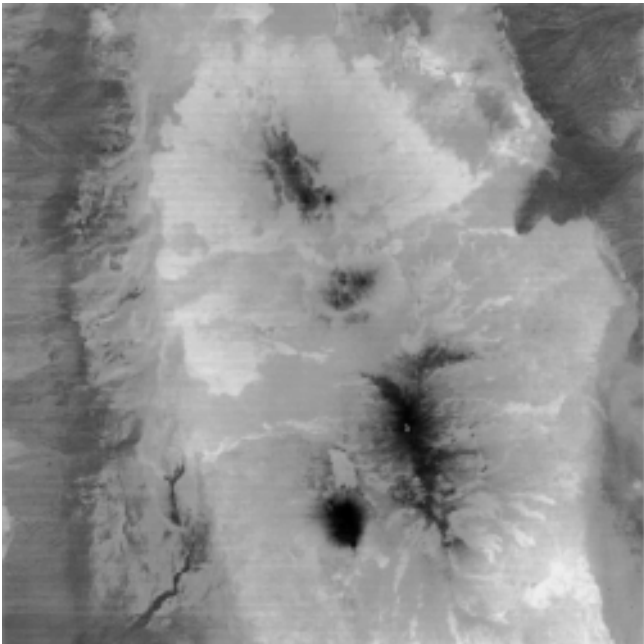


Subset of MODIS first image over the Mississippi River Delta region, from Louisiana to Florida. This image shows the sediment plume associated with the Mississippi River discharge, the characteristic bird foot shape of the Mississippi River Delta and a series of barrier islands. In the channels between the barrier islands, sediment can be seen washing into and out of the back bay areas behind the islands.

ASTER First Image

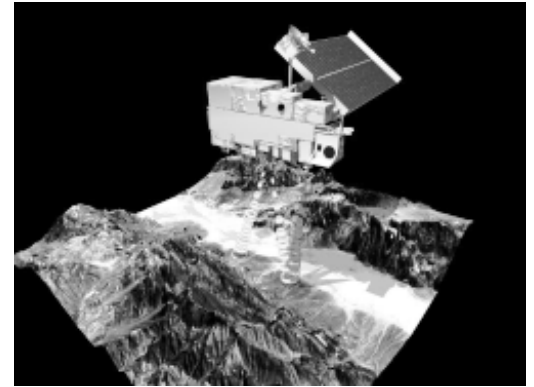


▲
IMAGE 1 : Visible/Near Infrared (VNIR) Image (monochrome). This image is from band 3N of the Visible/Near Infrared sensor of ASTER showing the channel and flood zone of the San Francisco River in Brazil. The surrounding area along the river channel in light gray to white could be covered by dense tropical rain forests. The water surface of the San Francisco River is rather gray in color as compared to the small lakes and tributaries, which could indicate that the river water is contaminated by suspended material. (The size of image: 20km x 20km approx., ground resolution 15m x 15m approx.)

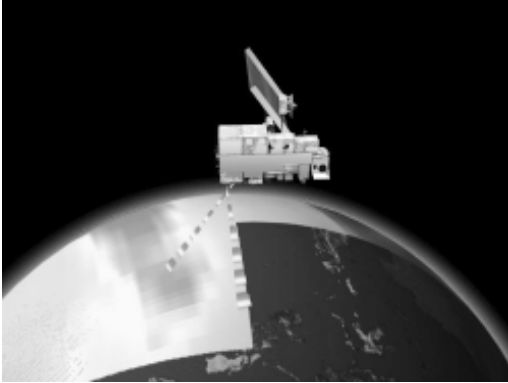


▲
IMAGE 2 : Thermal-Infrared (TIR) Image (monochrome) This is a night-time image, covering the Red Sea coastline to inland area of Eritrea, which Visible/Near Infrared (VNIR) and Shortwave Infrared (SWIR) sensors cannot do. White areas represent higher temperature surface material, while black areas represent lower temperatures. This shows ASTER's ability as a highly sensitive temperature-discerning instrument and the first spaceborne TIR multi-band sensor in history. (The size of image: 60km x 60km approx., ground resolution 90m x 90m approx.)

◀
IMAGE 3 : Thermal-Infrared (TIR) Image (original in color). This image is a composite covering the Rift Valley inland area of Ethiopia (south of Image 2). The shading of this image reflects the distribution of different rocks with different amounts of silicon dioxide. It is inferred that the area with whitish color is covered with basalt, and the slightly darker area in the center with andesite. This is the first image in history for the spaceborne TIR multi-band image enabling scientists to distinguish between rocks with the same composition. (The size of image: 60km x 60km approx., ground resolution 90m x 90m approx.)



CERES First Image



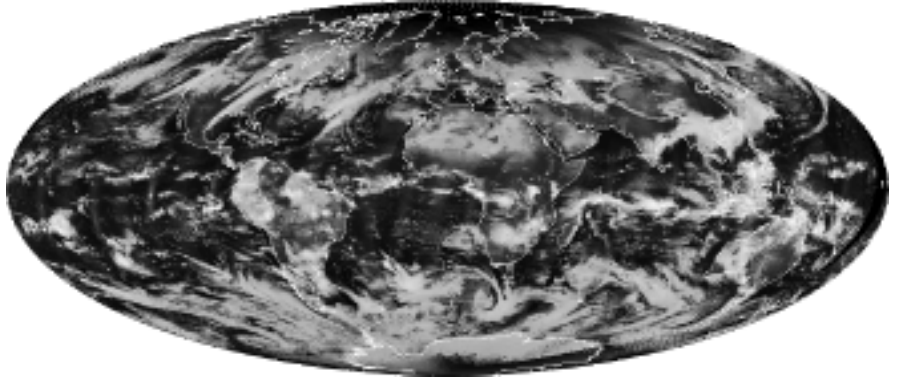
The two CERES instruments on Terra successfully opened their contamination cover doors on Friday, February 25, 2000.

The first image shows reflected solar radiance emerging from the top of the atmosphere, as measured by the CERES Flight Model 1 (FM1) instrument on the Terra spacecraft. These preliminary (unvalidated) data show 24 hours of measurements covering the entire Earth. Where there are no clouds over the oceans, the image is very dark. Where the oceans are lighter, there are clouds reflecting sunlight back to the CERES instrument. The tropical oceans near the Equator show intense thunderstorms. A cold front is seen west of the Appalachians and a storm over the Northwest Pacific Coast.

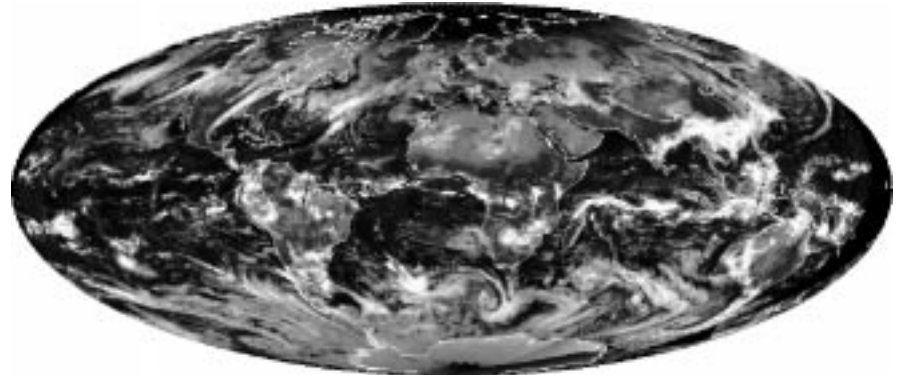
The second image shows the reflected solar flux emerging from the top of the atmosphere. These data are Level 2 data, which means that CERES has been able to get a reasonable “engineering” calculation of derived physical fields within a few days of opening its covers. The data shown come from Saturday, February 26, 2000, the first full day of FM1 scanning. Most of the patterns visible away from the Equator are large storm systems where clouds reflect a large fraction of the incident sunlight.

The third image shows the energy being lost from the Earth and the atmosphere by thermal emission. This process, familiar to most of us as the heat radiated by electric stove elements, involves light with wavelengths invisible to the eye. These data are Level 2 data from Saturday, February 26, 2000. Near the center of the image, the Saudi Peninsula stands in contrast with the warm waters of the Indian Ocean. The Sahara Desert appears to have fairly extensive cloud cover, particularly near the Mediterranean. Along the Equator from the Amazon Basin in South America, across the Atlantic to the Congo Basin, and then over the Indian Ocean, tops of very high thunderstorms in the Intertropical Convergence Zone can be seen.

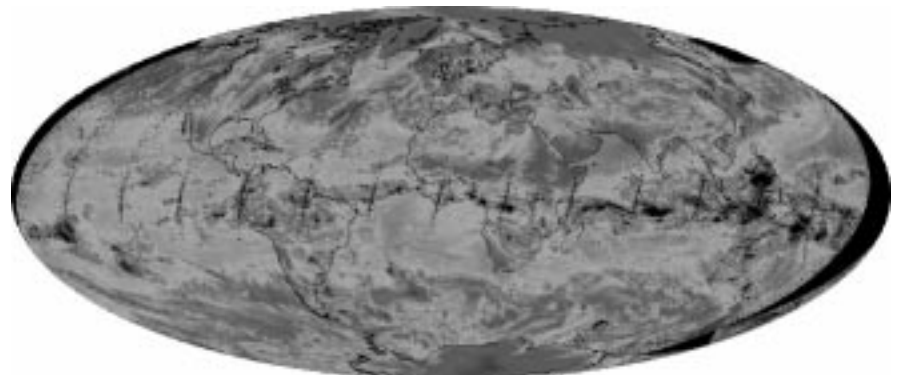
Reflected Solar Radiance
Preliminary data: February 26, 2000



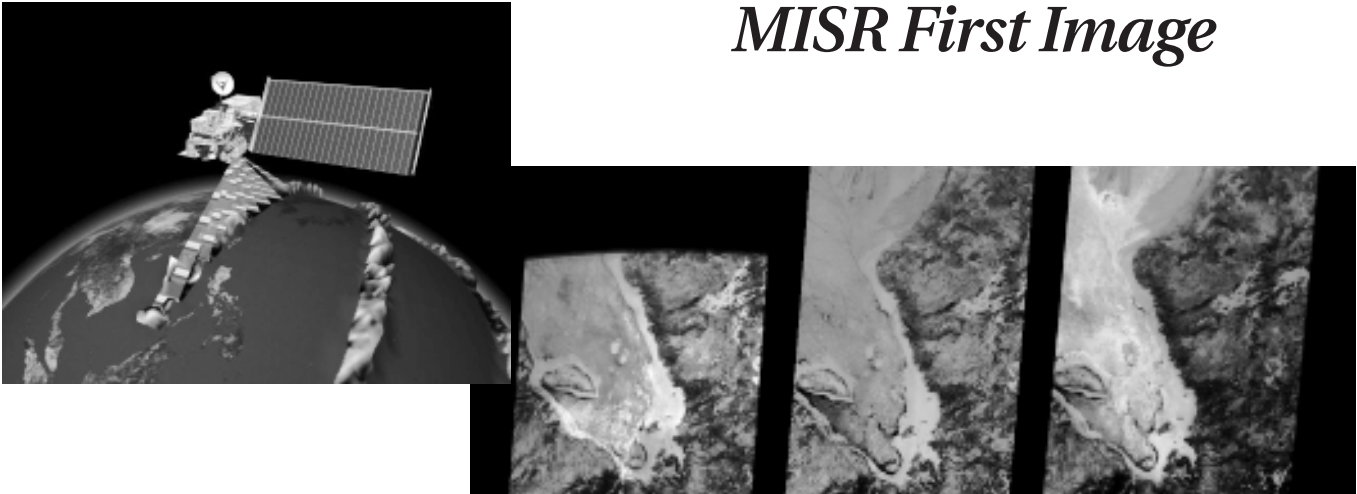
Reflected Solar Flux
Preliminary data: February 26, 2000



Emitted Thermal Flux
Preliminary data: February 26, 2000

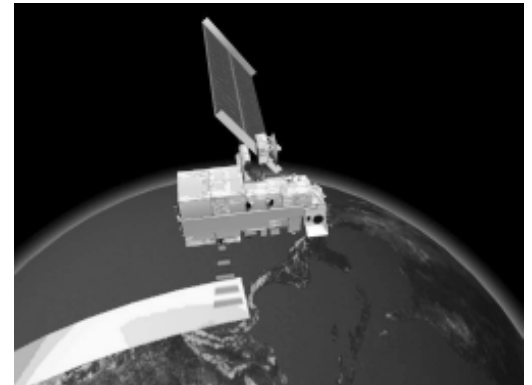


MISR First Image

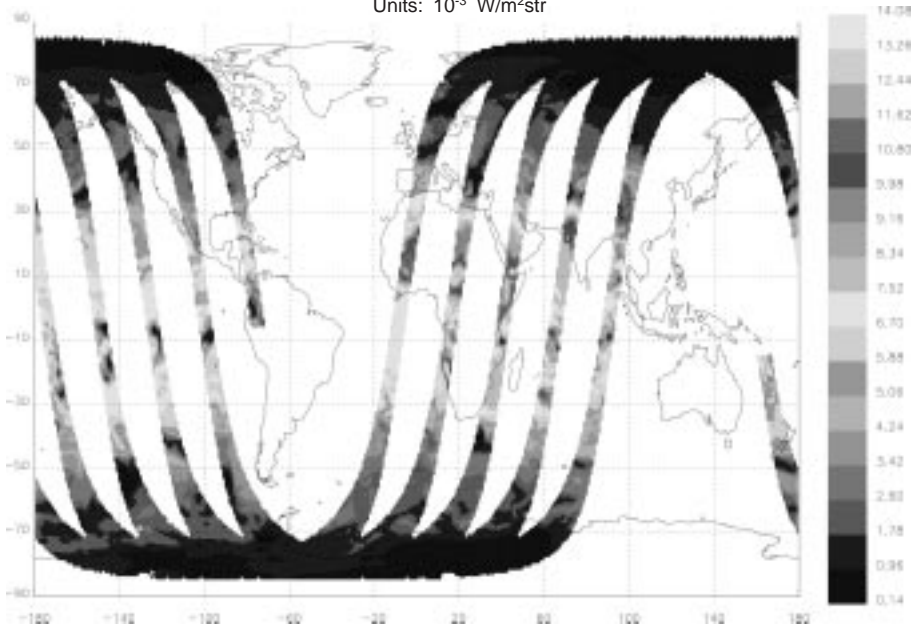


First light over James Bay, Ontario, Canada, acquired by NASA's Multi-angle Imaging SpectroRadiometer on February 24, 2000, shows this winter landscape from three of the instrument's nine cameras. The image at left captures the opening of MISR's cover and was recorded by the most oblique forward-viewing camera, which images the Earth at 70 degrees relative to a vertical plane. Several islands, including the crescent-shaped Akimiski Island, are visible in the frozen bay. The center image, acquired a few minutes later, was taken by the nadir camera, which looks straight down, and the image on the right, acquired seven minutes after first light, was taken from the most oblique aftward-viewing camera. Capturing swaths 400 kilometers wide, MISR can detect objects as small as 275 meters in diameter.

MOPITT First Image



Channel 1 Difference Radiances
 Mar. 03, 2000 01:59:58.1 to Mar. 03, 2000 11:59:46.8
 Units: $10^{-3} \text{ W/m}^2\text{sr}$



MOPITT measures radiances in several channels to determine the amount of carbon monoxide (CO) and methane in the atmosphere. Channel 1 difference radiances, shown here, are sensitive to the temperature of the Earth's surface, the temperature of the atmosphere, and the amount of CO. Of these, the first two effects dominate. Thus, we see lighter gray areas indicating high radiances and high surface temperatures from the subtropical deserts (Sahara, Arabian, Rajasthan and Kalahari). The dark areas indicate low surface temperatures (polar regions) or high clouds, as the line of clouds of the Intertropical Convergence Zone at about 10° S.

The intuitive nature of these results, the correspondence of variations with coast-lines and their similarity to expected values, indicate that the MOPITT instrument is functioning very well.

To recover the amount of CO, it is necessary to combine difference measurements like these with other MOPITT measurements of the radiation from the Earth's surface, and independent data on the atmospheric temperature, to remove these effects and get at the subtle effects of CO. This effort is now underway.

Overview of the Upcoming EOS Investigators Working Group Meeting

— Jim Closs (jim.closs@gsfc.nasa.gov), EOS Project Science Office

The next EOS Investigators Working Group meeting will be held April 11-13 at the Hilton East hotel in Tucson, Arizona. The IWG meeting is the primary and most comprehensive forum for sharing EOS program activities and scientific studies. The meeting is held nominally every nine months, and the location usually alternates between eastern and western U.S. venues. This year's meeting location is in the beautiful East side of Tucson, not far from historic Old Tucson and the University of Arizona. The hotel is 20 minutes from the Tucson International Airport.

The structure of the meeting will be a combination of plenary sessions highlighting EOS program activities, a series of discipline-specific science sessions, and a period of break-out working group meetings. Numerous posters on diverse EOS topics will also be presented for the duration of the meeting.

The specific agenda for the Tucson meeting is being finalized at this time, but the schedule will begin with a programmatic session on the Earth Science Enterprise (ESE) and EOS Program chaired by EOS Senior Project Scientist, Michael King. Ghassem Asrar, NASA Associate Administrator for Earth Science, will present the current status and future of the Earth Science Enterprise. Jack Kaye, Director of the Research Division, Office of

Earth Science, NASA Headquarters, will discuss the ESE Science implementation strategy, and Chris Scolese from the Goddard Space Flight Center will give an update on the EOS flight program. There will also be a presentation on EOS data processing and data system status, as well as Japanese and European space-program updates from the National Space Development Agency of Japan and the European Space Agency, respectively.

A 2-hour working lunch is planned for the first day, with various science working groups meeting in separate locations in the hotel. These groups include the Science Working Group for the AM Platform (SWAMP), the Aqua Science Working Group, and other Land, Climate, and Hydrology panels.


Overviews of Earth Science Information Partners (ESIPs) and Regional Earth Science Application Centers (RESACs) will be given, along with a summary of EOS Validation activities by David Starr. An evening reception hosted by the University of Arizona will be held in conjunction with an interdisciplinary poster session.

The second day of the meeting begins with a plenary science session co-chaired by Steve Running from the University of Montana and Eric Wood from Princeton

University. His session comprises five or six presentations on Land Processes and the Terrestrial Carbon Cycle. Wednesday afternoon begins a session on Atmospheric Processes and Chemistry chaired by Mark Schoeberl from Goddard Space Flight Center. This session will cover new science results from the TRMM, GOME, TOMS, and SOLVE campaigns.

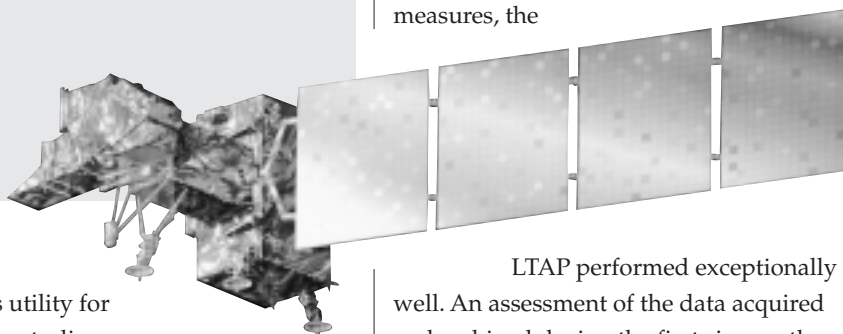
A special social event is planned for Wednesday evening. All meeting attendees are invited to tour the Biosphere 2 sealed ecosystem facility. Attendees will enjoy hors d'oeuvres and dinner under the beautiful Arizona sky. Throughout the evening, our group will have exclusive use of Biosphere 2, including private tours. Also, William Harris, President and Executive Director of Biosphere 2, will be on hand to personally welcome our group. This should be an extremely memorable tour, and very appropriate for a gathering of Earth Scientists. The cost is \$35 per person. If you are interested in attending, complete the information at the bottom of the registration form referenced at the end of this article and return to Mary Floyd at mfloyd@westover-gb.com.

An Ocean Processes and Biology session will be held Thursday morning, chaired by Michael Freilich of Oregon State University. Presentations in this session will cover QuikScat, SeaWiFS, TOPEX/Poseidon and other oceanography missions and their science results. The meeting will end Thursday at noon.

Registration and hotel information, along with a detailed agenda are available on the Calendar page of the EOS Project Science Office web site at eos.nasa.gov. I'm sure you share my anticipation for this important opportunity to share the latest EOS program and science activities. I hope to see you in Tucson. 

Report on Landsat Science Team Meeting

— Darrel Williams (darrel@ltpmail.gsfc.nasa.gov),
Landsat Project Scientist, NASA Goddard
Space Flight Center



The Landsat 7 Science Team held its seventh semi-annual team meeting October 12 - 14, 1999, at the NASA Goddard Space Flight Center. Representatives from all 14 investigations attended, as did representatives from NASA, USGS, and other government and commercial interests. Landsat 7 Project Scientist, Darrel Williams (NASA GSFC), and Science Team Leader, Samuel Goward (University of Maryland), chaired the meeting.

The gathering marked the first meeting since the successful launch of the Landsat 7 spacecraft on April 15, 1999. The spacecraft attained its operational orbit on June 28 and completed its on-orbit verification (including instrument checkout) on July 15, with the data archive being opened to the public in early August. At the time of the team meeting, over 30,000 full ETM+ scenes had been archived at the USGS EROS Data Center (EDC), and image quality appears to be excellent.

The meeting began with a briefing from Garik Gutman (NASA HQ), newly appointed NASA Program Manager for both the Landsat 7 and Land-Cover/Land-Use Change Programs. Gutman expressed his desire to work closely with the Landsat Science Team in the coming months. He also stressed the synergy between the two programs, which reflects

Landsat's utility for land-cover studies.

Ken Dolan (NASA GSFC) and R.J. Thompson (USGS EDC) presented a pair of briefings on the current operation of the Landsat 7 spacecraft and ground system. Dolan noted that for all practical purposes, operation of the spacecraft has been flawless since launch, and no major anomalies have occurred. Some concern was expressed regarding wear of the bumpers that cushion motion of the ETM+ scan mirror, but current forecasts of bumper wear do not show an impact on the instrument lifetime. Thompson noted that the EDC/EOSDIS processing system for Landsat 7 data is operational and serving data to customers. Current prices are \$475 for Level 0R images (no systematic correction) and \$600 for Level 1G images (calibrated and projected). Users can search the archive and order data via the URL at edcimswww.cr.usgs.gov/pub/imswelcome/.

Landsat 7 marks the first time in the history of the Landsat program that image acquisition has been scheduled on a global basis, using a cloud-avoidance algorithm and knowledge of seasonal vegetation cycles to optimize data collection for terrestrial research. Terry Arvidson (LMMS @ GSFC) and John Gasch (CSC @ GSFC) presented an overview and initial assessment of this Long-term Acquisition

Plan (LTAP). By November, Landsat 7 had acquired essentially complete global coverage, with at least one cloud-free scene available for most areas. By all measures, the

LTAP performed exceptionally well. An assessment of the data acquired and archived during the first six months of the mission (some 40,000 images) indicates that the overall quality of the Landsat 7 global archive is excellent. By choosing the best available image for each Worldwide Reference System (WRS) scene in the archive, one can already create a mosaic of clear images ($\leq 10\%$ cloud cover) covering 74% of the Earth's continental and coastal surfaces. Stated another way, 74% of all WRS scenes covering land were imaged at least once with cloud cover $\leq 10\%$; for a whopping 53% of the WRS' there is at least one scene in the archive with $\leq 1\%$ cloud cover. It has been well over a decade since such complete global coverage has been acquired, and never before has such cloud-free global coverage been acquired in such a short period of time. At the time of the meeting, 200-230 scenes were being archived at EDC each day.

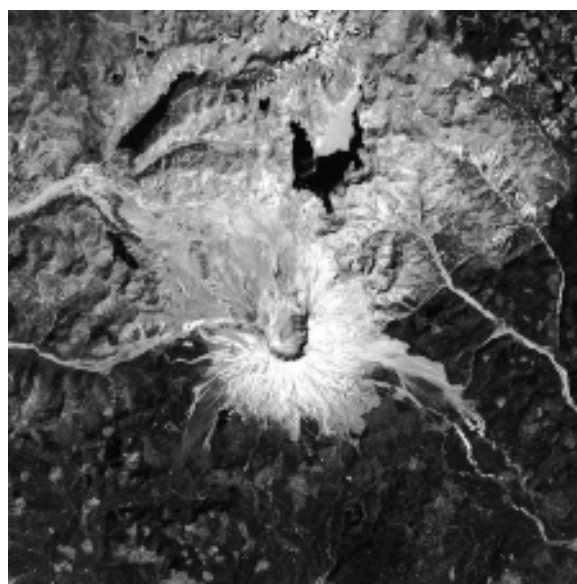
Brian Markham (NASA GSFC), John Barker (NASA GSFC), and Jim Storey (USGS EDC/RITSS) presented a comprehensive overview of the radiometric and geometric performance of the Landsat 7 ETM+ instrument. ETM+ appears to be functioning extremely well, with significantly lower per-pixel noise levels (~ 1 DN standard deviation) and improved radiometric stability compared to Landsat-5. Unfortunately, the internal calibration system (IC) fluctuates through time,

making the use of the IC problematic. However, the pre-launch calibration seems to be accurate, and users should continue to use the pre-launch calibration until the IC stabilizes. The geometric characteristics of ETM+ also improve on those of Landsat-5, with excellent band-to-band registration, and a geodetic accuracy (pixel-to-ground) of better than 100 m for systematically corrected images. Storey noted that by using post-pass ephemeris data, the geodetic accuracy could be improved to better than 50 m. This enhancement should become part of the standard EDC processing chain in April, 2000.

The remainder of the afternoon included presentations on: (a) the analysis strategy for the Landsat-5/ Landsat 7 cross-calibration underfly (Phillip Teillet, Canadian Remote Sensing Center on sabbatical at GSFC), (b) educational outreach (Stephanie Stockman, SSAI @ GSFC), and (c) the current status of NASA's EOS-1 Landsat 7 follow-on mission, currently proposed as a data-buy from a commercial vendor (Jim Irons, NASA GSFC). Stephen Ungar (NASA GSFC) also presented an update of the EO-1 mission, which includes advanced technologies for next-generation Landsat-type observations. Ungar indicated that the mission was currently scheduled for a December 1999 or January 2000 launch (note – this has now been pushed to July, 2000). A Science Team to validate data products from the EO-1 mission has also been selected.

Samuel Goward discussed a new software product, LPGA-lite, being produced by the University of Maryland. LPGA-lite is designed to be a stand-alone, platform-independent Level 0R to Level 1G converter for Landsat 7 imagery. Thus,

users may purchase less expensive LOR data and handle radiometric calibration and systematic corrections themselves. The package will be distributed via the University of Maryland Global Land Cover Facility (<http://glcf.umiacs.umd.edu/>). The first day concluded with a talk by Joanne Gabrynowicz (University of North Dakota) on remote-sensing policy entitled "Expanding Global Remote Sensing Services: The State of Remote-Sensing Law and Policy at the Turn of the 21st Century."



Mt. St. Helens - still showing the effects of the massive eruption that occurred on May 18, 1980. Landsat 7 acquired on August 22, 1999

The second day began with a presentation from Jack Kaye, recently appointed Director of the Research Division, Office of Earth Sciences at NASA Headquarters. Kaye noted that NASA was reevaluating the merit of supporting separate instrument teams, and was instead looking at mechanisms for supporting more-basic scientific research. He also stressed NASA's role in investigating the physical Earth Sciences, and suggested that socioeconomic investigations could be left to other Federal agencies.

Following a short discussion, representatives from the 14 funded Landsat 7 investigations gave 30-minute progress reports on their research. For the first time, investigators were able to report on results using Landsat 7 ETM+ imagery. First assessments of the Landsat 7 data quality were uniformly positive, with several investigators noting the reduced noise content of ETM+ data, and the utility of the 15-meter-resolution panchromatic band. Problems were noted in the initial processing of the thermal band, with striping appearing in the high-gain

version of these data. This problem was determined to be a software problem, and corrections were made to remedy the problem shortly after the meeting. Please note that the quality of the data in the archive was not affected by this software glitch at all.

The final day of the meeting commenced with two talks on outreach activities. Steve Cole (RITSS @ GSFC) outlined strategies for disseminating early science results to the news media, and Samuel Goward discussed an opportunity to contribute articles for an upcoming special issue of *Remote Sensing of the Environment* dedicated to the Landsat 7 mission. Tom Stanley (NASA Stennis Space Center) gave a presentation on the

Space Imaging IKONOS mission, and invited Science Team members to contribute acquisition requests as part of the NASA data buy program.

The next Science Team meeting will be held May 9 – 11, 2000, in Boulder Colorado on the campus of the University of Colorado. Those wishing to participate should contact Jeffrey Masek, e-mail: jmasek@geog.umd.edu, Deputy Science Team Leader, at the University of Maryland.

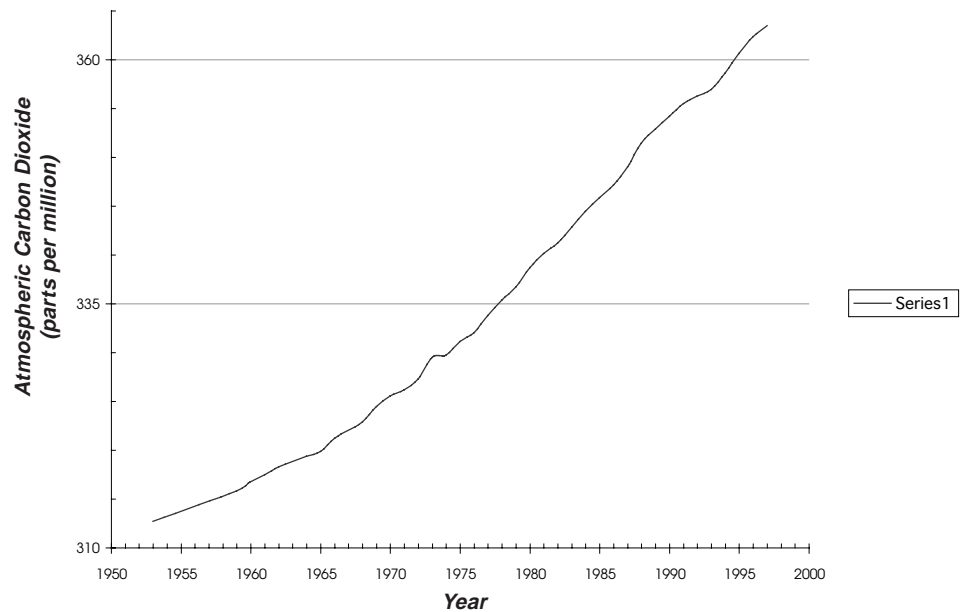
Why the Earth Observing System matters to all of us

— Steve Running (*swr@ntsg.umt.edu*), School of Forestry,
University of Montana, Missoula, MT



At the end of this millennium it is appropriate for us to reflect upon the world we are passing on to our children. We are the first generation in human history with the capacity to impact the entire global system. Atmospheric CO₂ concentrations have been measured carefully since 1957 at Mauna Loa, and the increase has been steady at about 0.3% per year since then, a direct result of fossil fuel combustion. Atmospheric CO₂ in itself is not dangerous—it actually helps plants grow faster. But scientists see it as a “canary in the coal mine,” the leading indicator of other global-scale human impacts on the biosphere, the sum total of living organisms on the land and in the oceans. Whether the collective impacts of humans on the Earth are benign, or on a trajectory to future disaster is an ethical question we must now confront. However, studying the entire Spaceship Earth as a functioning Earth System had never been tried before, until now.

In July 1983, NASA published with little fanfare, the report of a small group of scientists aptly named *Land-Related Global Habitability Science Issues*. This brainstorming by about 20 scientists, including myself, was a first attempt to think how the entire Earth could be monitored carefully and continuously to evaluate global-change trends. NASA spent the rest of the 1980s designing a system to



The concentration of carbon dioxide in the atmosphere has increased from 310 to over 360 parts per million in the past 50 years. Carbon dioxide traps heat near the Earth’s surface, and its increase may lead to global warming. (Graph by Robert Simmon, based on data from the National Oceanic and Atmospheric Administration.)

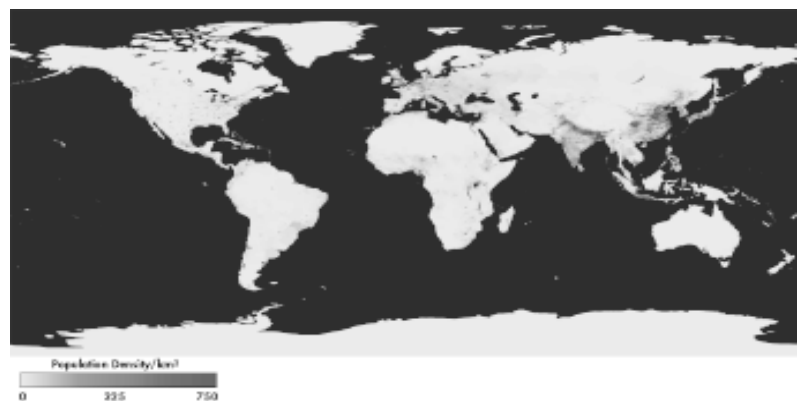


Figure 2. The areas of the world with the highest population densities—China and Southeast Asia—are rapidly industrializing. Considering the environmental record of industrialized countries, these developing nations will face important decisions between rapid growth and environmental stewardship. (Map by Robert Simmon, based on data from the Center for International Earth Science Information Network.)

measure global habitability, and the Earth Observing System (EOS) was conceived in 1990. On December 18, 1999, maybe fittingly at the end of this millennium, we launched the first satellite designed to fulfill this vision. (Note: the Terra satellite was launched December 18, 1999.) The one-line summary of the purpose of EOS is to find out: "Is the current human occupancy and activity of planet Earth sustainable?"

It is the moral imperative of our generation to pass on to our children and grandchildren a world that is equal in habitability to the world our parents gave to us. The problem is that as the global population passes 6 billion people, even if individual resource consumption stayed constant, impacts on the biosphere will increase. However, we seem to be living in bigger houses, driving fancier cars, and flying off to more vacations than our parents did, so per capita resource consumption is not staying constant at all, but increasing. And the developing world is desperately trying to catch up to the living standards of the developed countries. Many developing countries are also making the same mistakes of "development at whatever the environmental cost" that we made 30 years ago. We learned back then that rivers catching on fire and air pollution that forces schoolchildren to stay in at recess is unacceptable. The progress in cleaning up regional pollution in the United States has been remarkable in the last few decades. But now at the end of the 1990s, as we see a globalized economy, we also see a globally interconnected environment.

Documenting and monitoring biospheric health, just like human health, should not be a political topic. Biospheric health, and more specifically the sustainability of human life on planet Earth, is a topic that cuts across liberals and conservatives,



Figure 3. In 1940 New York was the world's largest city, with 7.4 million inhabitants. By 1997 it had dropped to tenth, replaced by Seoul, South Korea's 10.2 million residents. The global population has grown rapidly in the past 50 years. Consequently, humanity's impact on the environment is increasing. We need to understand the environment to accurately judge the effect we have on it. (Photograph from the National Archives and Records Administration.)

Republicans and Democrats. We all want the best for our grandchildren, and to pass on to them a livable world. However, until now, global biospheric health has been largely unmeasurable, so discussions and policy development have been handicapped by a paucity of data.

The purpose of EOS is to provide this factual information on trends of change in our biosphere. How we interpret these data, and the course of action we embark on in the next millennium will be a critical political topic. If global-change trends turn out to be relatively modest, then only small adjustments in social behavior may be necessary. However, if impacts appear to be harmful and accelerating at an unpredictable pace, how can we ignore these early warnings in good conscience? It is essential that the new political discussion be based on facts, not conjecture.

These are lofty, long range, visionary objectives, similar intellectually to searching for other life in the universe. But global habitability has more immediate significance to us all. Let us hope that EOS allows us to start the new millennium with an enlightened understanding of the changing biosphere.



NASA's Global Change Master Directory



Discovery Source for Earth Science Data

— *Lola Olsen (olsen@gcmd.gsfc.nasa.gov), NASA
Goddard Space Flight Center*
— *Gene Major, Raytheon ITSS*

gcmd.nasa.gov

The Global Change Master Directory (GCMD) is a discovery source holding information that allows searchers to determine useful Earth science data sets for their needs. The GCMD continues to gain momentum in its quest to identify and link to Earth science data. More than 1000 EOS data sets and about 7000 other Earth science data sets from federal agencies, universities, research institutes, and international organizations are described in the directory, which is available at URL: gcmd.nasa.gov.

The GCMD gained an early presence on the Web in 1994, when unique users per month averaged in the low hundreds. An indication of the value of the GCMD is that it now attracts about two orders of magnitude more users per month (~20,000). The number of Earth science data sets described in 1994 was less than 2000. Since that time, the number of data set descriptions has quadrupled. The challenge is that there are tons of data out there yet to be discovered.

After the release of the Directory's version 6 system, MD6, in 1998, usage was assessed for a number of experimental interfaces and their associated search engines. By tracking the number of data set descriptions being accessed, users were found to be discovering and linking to

data sets most successfully through a hierarchical science keyword interface, where scientific parameters and keywords can be selected. Therefore, with the release of version 7, MD7, the hierarchical keyword interface was designated as the primary search option (the "default" interface). The science keyword search "normalizes" the search for data because every data set description carries the Earth science keywords that describe the contents of the data set. The construction of the Earth science keyword hierarchy took several years of effort and has since been recognized and adopted by other Earth science groups, such as the Department of Defense's Master Environmental Library (MEL). The key to the continued success of the keyword hierarchy could possibly be in the acceptance of a set of 15 rules that are employed when additions or modifications are suggested. Keyword definitions are now available to users online during their searches. The response to MD7 has been gratifying, and the rate at which data set descriptions are being received is accelerating. Another indication of the value of the GCMD is that a number of commercial search engines rank the GCMD first when searching for global change. This ranking is based on the number of other web sites that link to the GCMD.

Alternative interfaces and their associated search engines are available for users with different computer capabilities and varied preferences for searching. Along with the familiar free text search, is the matrix interface based on a Java implementation. The Java applet takes some time to download but then performs lightning-fast queries using all the fields that hold controlled keywords. A popular search alternative, designed in conjunction with the University of Maryland's Human Computer Interaction Laboratory (HCIL), provides graphical displays of the results showing the data distribution over several attributes. This interface is called the dynamic query interface and is described in an article entitled, "The end of zero-hit queries: query previews for NASA's Global Change Master Directory" in the *International Journal on Digital Libraries* [Greene, S., E. Tanin, C. Plaisant, B. Shneiderman, L. Olsen, and G. Major, 2:79-90, September 1999].

Data sets are described using the content and syntax of the Directory Interchange Format (DIF). The DIF is widely accepted for its ability to keep pace with rapid technological changes. Changes to the DIF are made through the Interoperability Forum, where participants discuss needed modifications. One important search field, *Paleo_Temporal Coverage*, was added for MD7 to handle start and stop dates before the year 0 to accommodate the growing number of paleoclimate and geologic data set descriptions. Also, several fields were modified to better assist in maintaining data set history. The Forum was also instrumental (for MD6) in recommending a solution for describing and representing interconnected collections of data sets. To assure that data sets are described at an appropriate level of detail, a parent-child hierarchical relationship was developed.

Also new with MD7 is the GCMD

Subscription Service, which allows users to specify their data interests. When data sets fitting the parameters specified are added to the database, data set descriptions are automatically e-mailed to requestors without their having to search repeatedly.

In addition, the Global Change Conference Calendar was placed in a relational database. The calendar holds hundreds of links to upcoming conferences, along with an archive of past conferences. An experimental Learning Center has been added to respond to common Earth science questions received through the GCMD's user support office. The Learning Center is experiencing increased activity as part of educational outreach efforts. It is also frequently suggested as a resource in response to "Ask Dr. Global Change" questions that are fielded by the U.S. Global Change Research Program's (USGCRP) Global Change Research Information Office (GCRIO).

Mirror sites of the directory's content are available in many other countries through the Committee on Earth Observation Satellites' (CEOS) International Directory Network (IDN). These sites serve thousands of additional users. The GCMD has developed customized free-text search interfaces to allow partners to maintain their identify and intellectual ownership. Queries of virtual subsets through customized free-text search interfaces have been established with the following partners:

- The U.S. Department of Agriculture (USDA) agriculture subset. Users can search for USDA and agriculture-related data sets.
- The Earth Science Information Partners (ESIP) Federation subset. Users can search all of the ESIP Types I, II, and III data set descriptions

(which include all of the Type I EOSDIS DAAC data sets).

- The Antarctic Master Directory (AMD) subset, where users can search through Antarctic-related data set descriptions.
- In the near future, the GCMD will assist in developing interfaces to search subsets of the Global Observing System.


Recently, the directory implemented a new hardware architectural solution that significantly increases the speed and reliability of the GCMD. A paper describing this innovative architecture will be presented at an upcoming conference of Earth Observation/GEOspatial (EO/GEO 2000) applications in London in April. The solution involves the use of a PC proxy server, which serves a caching function and directs users to one of two back-end UNIX computers. The current operational system was written (in Perl) to improve database access/loading times, to make future modifications more efficiently, and to prepare for the object-oriented scope of future versions. Developers continuously monitor rapidly exploding technology and are capitalizing on pertinent advancements. Flexibility in importing and exporting descriptions in other metadata formats is presently done using Standard Generalized Markup Language (SGML). In the future, style sheets associated with the eXtensible Markup Language (XML) will be used to display descriptions in any number of other formats. The next release of the directory expands on object-oriented technology and will fully support XML technology, providing the capability to both produce and consume XML metadata. The specification to describe this metadata is called the Document Type Definition (DTD). This specification provides a means of standardizing the syntax and semantics of the metadata (DIF) so that any incoming XML metadata

can be both validated and propagated among participants.

A science User Working Group (UWG) for the GCMD was assembled in 1994 to provide guidance and feedback on the multidisciplinary project. The current members of the UWG are John Porter, University of Virginia, and Bernard Minster, University of California, San Diego, who serve as co-chairs; Elissa Levine, NASA/Goddard Space Flight Center; Lou Steyaert, USGS; Jonathan Callahan, NOAA/PMEL; Benno Blumenthal, Lamont-Doherty Earth Observatory of Columbia University; Andrea Buffam, Canada Centre for Remote Sensing; and Wendell S. Brown, University of New Hampshire.

The GCMD's web site was one of a number of sites recently reviewed by an External Web Review panel, organized by Goddard Space Flight Center. Reviewers included John M. Horack, of Science Communications, Inc.; Lee Andrew Jung of Yahoo! Inc.; Diane Kisich of University of California, Berkeley; Paul Ruscher, Florida State University; Rick E. Borchelt, Vanderbilt University; and Nan Broadbent, AAAS. Following is their summary of the site:

"The review panel found this to be a high-quality site. The front page made a favorable impression, and the purpose of the site was clear. This was reflected in the layout and design. The site conveyed an excellent customer-service attitude. FAQ sections were well done. The site downloads very quickly. The javascript information window was both appropriate and useful. Reviewer went from the front door to an Optical Transient Detector data set in less than 5 minutes, complete with the Principal Investigator's phone number. Any scientist or graduate student should be able to use this site."



NASA Satellite Greatly Improves Accuracy of Tropical Rainfall Forecasting

— David E. Steitz (*dsteitz@mail.hq.nasa.gov*), NASA Headquarters, Washington, DC
— Allen Kenitzer (*alemotze@pop100.gsfc.nasa.gov*), Goddard Space Flight Center, Greenbelt, MD
— Stephanie Kenitzer, American Meteorological Society, Washington, DC

New research shows that adding rainfall data from NASA's Tropical Rainfall Measuring Mission (TRMM) satellite and other meteorological satellites to forecast models can more than triple the accuracy of short-term rainfall forecasts.

These findings by researchers at Florida State University, Tallahassee, FL, were presented recently at the annual American Meteorological Society's (AMS) meeting in Long Beach, CA, and will be featured in an upcoming edition of the *Journal of Climate*.

In addition, researchers found that using the rainfall data collected from defense meteorological satellites and TRMM can be used to increase the forecast accuracy even further. Their method examines the behavior of a number of different forecast models and selects those properties from each model that lead to the true rainfall as observed by the TRMM satellite. These model properties are then used to predict the rainfall for three days into the future, with remarkable success.

"Including rainfall into the multi-forecast model, or 'superensemble' model, is a unique approach," said Prof. T.N. Krishnamurti, the paper's lead author and a TRMM scientist at Florida State Univer-

sity. "Overall we're most interested in improving the rainfall three-day forecast accuracy. Our research has shown that the accuracy of global and regional forecasts using the superensemble is higher with TRMM research data."

These forecast results are based on five experiments, each conducted August 1 to August 5, 1998. The forecast accuracy was higher over all tropical regions. Scientists attribute this success to a combination of improved analyses available from the superensemble approach as well as the availability of accurate rainfall estimates over the tropics from the TRMM satellite.

For years, scientists have attempted to improve the short-term forecasts in the tropics, but only minor improvements were made. Now, with the research data from the NASA spacecraft, scientists will more accurately forecast rainfall in the region. This is particularly important when it comes to hurricane tracks and rainfall accumulations. Experimental forecasts made by this new technique during the 1999 hurricane season, for example, correctly forecast the track of major hurricanes such as Dennis and Floyd.

Scientists have a keen interest in how potential changes in the global climate might affect the associated rainfall patterns as they, in turn, affect human activities. "Making such improvements in even the short-term forecasts is important because it demonstrates that we are learning more about the behavior of rainfall within these models," said Chris Kummerow, the spacecraft project scientist at Goddard Space Flight

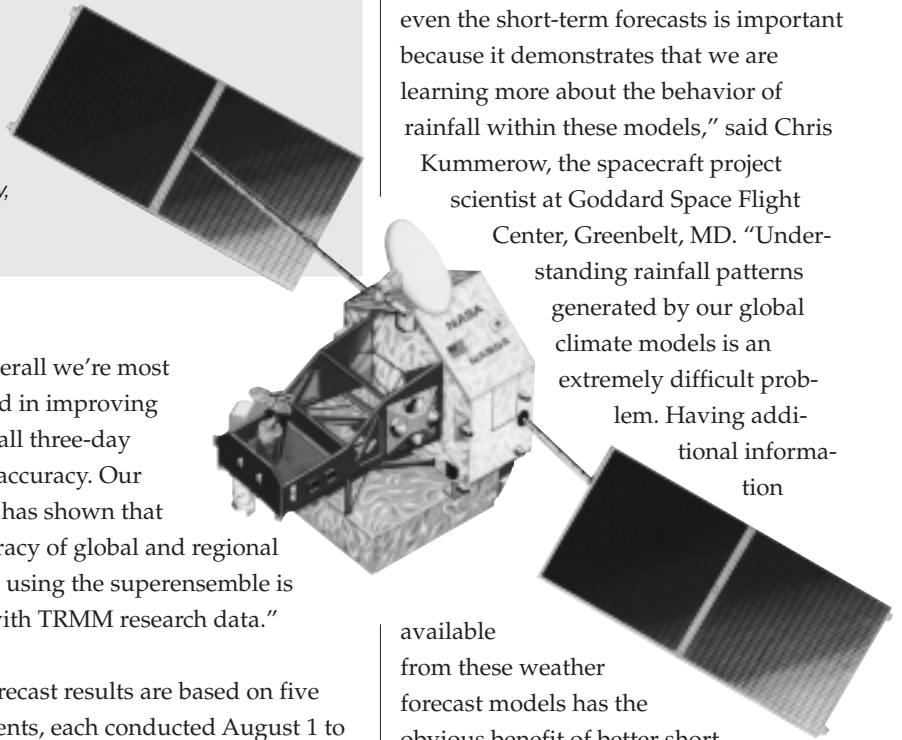
Center, Greenbelt, MD. "Understanding rainfall patterns generated by our global climate models is an extremely difficult problem. Having additional information

available from these weather forecast models has the obvious benefit of better short-term forecasts, and may help shed additional light upon the climate models."

TRMM is NASA's first mission dedicated to observing and understanding tropical rainfall and how it affects the global climate. The TRMM spacecraft fills an enormous void in the ability to calculate worldwide precipitation because ground-based radars that measure precipitation cover so little of the planet. "Ground-based radars cover only 2 percent of the area covered by TRMM," said Kummerow.

TRMM has produced continuous data since December 1997. Tropical rainfall, between 35° N and 35° S, comprises more than two-thirds of the rainfall on Earth. Previous estimates of tropical precipitation

(Continued on page 15)



EOS Scientists in the News

— *Emilie Lorditch (elorditc@pop900.gsfc.nasa.gov), Raytheon ITSS*

Science News' top Earth Science stories of 1999 (Dec. 18 & 25):

"Indian Ocean Temperatures Were Found To Herald Epidemics" with research by **Assaf Anyamba** (NASA GSFC) that looked at using El Niño as a predictor of Rift Valley Fever.

"Scientists Studied Ways to Adapt to Climate Change" with research by **Cynthia Rosezweig** (NASA GISS) looks at ways for New York City to adapt to future climate change.

"Aging TOPEX/Poseidon Satellite Still Sending Back Ocean Data," (Jan. 29) *Associated Press* by Matthew Fordahl. **Bill Patzert** (NASA JPL) reports that the satellite was designed to operate up to five years, but it is still going strong. Patzert says that the TOPEX/Poseidon satellite, which bridges the gap between ocean, climate, and weather has performed better than expected and with more precision.

"Hawaii Scientist Eyes NASA Launch," (Jan. 28) *Star-Bulletin* (Hawaii) by Helen Atlon. **Peter Mougini-Mark** (Univ. of Hawaii) says that the space shuttle Endeavour mission will increase our knowledge of the Earth's topography and answer many unanswered questions about volcanic research.

"Southern Ocean Soaks Up Carbon Dioxide," (Jan. 28) *Environmental News*

Network. **Ken Caldeira** (Livermore National Laboratory) says that manmade carbon dioxide is being soaked up by the Southern Ocean and moved north to the waters of the subtropics. Caldeira suggests that the ocean's ability to soak up carbon dioxide may be hindering global warming.

"Arctic SOLVE Mission Living Up To Its Name," (Jan. 27) *Environmental News Network*. NASA's **SOLVE** field campaign is measuring ozone levels and changes in the upper Arctic atmosphere during the winter. The researchers on the mission are using ground-based instruments, satellites, airplanes, and balloons to measure the atmosphere.

"Mapping the Earth, Swath by Swath," (Jan. 25) *New York Times* by Warren E. Leary. **Victor Baker** (Univ. of Arizona) says that the radar maps from the space shuttle Endeavour's mission will help his research on flooding and the flow of rocks and debris along waterways.

"University of Arizona Scientists Hoping Satellite Sheds Light on Global Warming," (Jan. 22) *Tucson Citizen* by Joyesha Chesnick. **Roger Davies** (Univ. of Arizona) will use NASA's Terra satellite to answer questions about global warming. Davies says that the data gathered from Terra could eventually help prove or disprove the global warming theory.

"La Niña May Be Part of Bigger Climate Change," (Jan. 20) *Associated Press* by Matthew Fordahl. **William Patzert** (NASA JPL) says that the persistence of warmer than average ocean temperatures reveal that there is more than an isolated La Niña influencing the Pacific Ocean. Patzert says that these climate observations will help farmers, water managers, and emergency planners to plan ahead for climate changes.

"Satellite Refines Rainfall Forecasts," (Jan. 19) *Environmental News Network*. **Chris Kummerow** (NASA GSFC) says that Tropical Rainfall Measuring Mission data have tripled the accuracy of short-term rainfall forecasts and that these data can also improve long-term climate models.

"Sultry 1990s Light a Fire Under Theory of Warming," (Jan. 14) *Knight Ridder* by Seth Borenstein. **Roy Spencer** (NASA MSFC) says that it is difficult to argue against global warming during a very warm year combined with a La Niña. The National Research Council recently released a report that stated there were increased global temperatures last year, which has strengthened the case for global warming.

"\$1.3 Billion Satellite Links Tahoe to NASA," (Jan. 13) *Tahoe World* by Shannon Darling. **Simon Hook** (NASA JPL) worked with the Terra science team to prepare small rafts that will float in the middle of Lake Tahoe and take temperature readings to compare with the temperature readings from NASA's Terra satellite.

"Official Word on Climate Change Incomplete?," (Jan. 12) *Discovery Online*. **Roger Pielke Sr.** (Colo. State Univ.) thinks that the reports published by the Intergovernmental Panel on Climate Change are missing an important part of climate research. Pielke says that the reports fail to look at climate as an integrated system

and to include human-induced land-use changes and how plants change with increased levels of carbon dioxide in the atmosphere.

"La Niña Used to Predict Floods," (Jan. 6) *Associated Press*. **William Patzert** (NASA JPL) has been examining the current La Niña cooling of the Pacific Ocean. Based on the expected rainfall and snowfall levels, rivers in the Northwest and on the East Coast of the United States are likely to rise beyond normal levels over the next six months, says Patzert.

"Arctic Expert Unthaws Alarming Data on Ice Thinning," (Jan. 3) *CNN Interactive* by Jack Hamann. **Andrew Rothrock** (Univ. of Wash.) has been taking measurements of North Pole ice and found that Arctic ice is thinning by 4 inches (10 cm) a year. Rothrock says that if the Arctic continues to melt, the Gulf Stream may be diverted south causing extremely cold winters in the northern Atlantic.

"A Sign of Healing Appears in Stratosphere," (Dec. 18 & 25) *Science News* by Richard Monastersky. **James M. Russell** (Hampton Univ.) has found that the levels of harmful chlorine pollution in the Earth's stratosphere are decreasing. Russell says that this is a sign the ozone layer is beginning to recover from 70 years of chemical assault.

Note: EOS researchers please send notices of recent media coverage in which you have been involved to:

Emilie Lorditch, EOS Project Science Office, Code 900, Goddard Space Flight Center, Greenbelt, MD 20771
Tel. (301) 441-4031; fax: (301) 441-2432;
e-mail: elorditc@pop900.gsfc.nasa.gov



(Continued from page 13)

NASA Satellite Greatly Improves Accuracy Of Tropical Rainfall Forecasting

were usually made on the basis of weather models and occasional inclusion of data from very sparse surface rain gauges and/or relatively few measurements from satellite sensors. The TRMM satellite allows these measurements to be made in a focused manner.

TRMM, a NASA-Japanese mission, is part of NASA's Earth Science Enterprise, a long-term research program designed to study the Earth's land, oceans, air, ice and life as a total system. Information and images from the TRMM mission are available on the Internet at URL: trmm.gsfc.nasa.gov/.

Information on the AMS is available at URL: www.ametsoc.org/.



What's on the EOS Project Science Office Web Site?? A wealth of information including the following:

Direct Broadcast Resources

URL: eospsso.gsfc.nasa.gov/eos_homepage/db.html

1999 EOS Reference Handbook

URL: eospsso.gsfc.nasa.gov/eos_homepage/misc_html/refbook.html

EOS Science Plan

URL: eospsso.gsfc.nasa.gov/sci_plan/chapters.html

EOS Validation Program

URL: eospsso.gsfc.nasa.gov/validation/StarrProject/HighTech/frame.html

Educational Materials

URL: eospsso.gsfc.nasa.gov/eos_homepage/educationpub.html

Terra Validation

URL: eospsso.gsfc.nasa.gov/validation/terraval.html

Aqua Validation

URL: eospsso.gsfc.nasa.gov/validation/pmval.html

El Niño's Dramatic Impact on Ocean Biology, Carbon Dioxide Captured by Unique Monitoring System

— Cynthia O'Carroll (cynthia.m.ocarroll.1@gssc.nasa.gov), NASA Goddard Space Flight Center

— Debbie Nail Meyer, Monterey Bay Aquarium Research Institute (tel. 831-775-1807)

— Jana Goldman, National Oceanic and Atmospheric Administration (tel. 301-713-2483)

The 1997-98 El Niño/La Niña had an unprecedented roller-coaster effect on the oceanic food chain across a vast swath of the Pacific, plunging chlorophyll levels to the lowest ever recorded in December 1997 and spawning the largest bloom of microscopic algae ever seen in the region the following summer.

According to new results published in the Dec. 10 issue of *Science*, El Niño also dramatically reduced the amount of carbon dioxide normally released into the atmosphere by the equatorial Pacific Ocean.

Data from an array of instruments on buoys, ships and in space, including NASA's Sea-viewing Wide Field-of-View Sensor (SeaWiFS), gave researchers an unprecedented view into the extreme biological effects of this El Niño/La Niña event.

"With SeaWiFS in orbit, we were able to see for the first time not only the vast size and intensity of the ocean's biological rebound from El Niño, but also the unbelievable speed of that recovery," said Goddard Space Flight Center (Greenbelt, Md.) oceanographer Dr. Gene Feldman, a co-author of the study. SeaWiFS provides daily views of the world's oceans and land masses.

Over the past decade scientists have been able to observe the development and progression of El Niño warmings, and consequent changes in upwelling of nutrient-rich ocean waters, thanks to data continuously collected in the Pacific by the buoys of the National Oceanic and Atmospheric Administration's Tropical Atmosphere Ocean array.

In 1996 new biological and chemical sensors were added to some of these buoys by the Monterey Bay Aquarium Research Institute (MBARI), allowing researchers for the first time to directly and continuously monitor biological productivity and the concentration of carbon dioxide in the region. The launch of SeaWiFS in 1997 added yet another ocean-monitoring tool capable of detecting subtle changes in ocean color that are directly related to the concentration of chlorophyll, a prime indicator of biological activity in ocean waters. The largest reservoir of chlorophyll in the ocean is in the phytoplankton (a microscopic form of algae), which forms the base of the oceanic food chain.

"This is the first time we've ever had a set of biological measurements from moored instruments and satellites during an intense El Niño, and we've never seen such low chlorophyll concentrations," said

MBARI biological oceanographer Francisco Chavez, lead author of the study. It was the buoy measurements and SeaWiFS data that revealed surprisingly low and then high levels of chlorophyll coinciding with El Niño's strongest phase and the recovery period and transition to La Niña cooling. When the warm-water layer produced by El Niño extended to its greatest depths and the upwelling of nutrients necessary for phytoplankton growth virtually ceased, chlorophyll values plummeted.

The researchers were again surprised in mid-1998 when chlorophyll levels skyrocketed, revealing the largest phytoplankton bloom, in area, ever observed in the equatorial Pacific. In their published results, the researchers suggest that elevated iron concentrations stimulated this intense bloom, a result of the increased upwelling associated with La Niña.

El Niño also drastically reduced the amount of carbon dioxide this ocean region adds to the atmosphere. Unlike most parts of the world's oceans, the equatorial Pacific is normally a major contributor to atmospheric carbon dioxide due to the carbon-dioxide-rich deep ocean waters brought to the surface here and the relatively low levels of biological activity.

The researchers calculate that the amount of carbon dioxide released to the atmosphere by the equatorial Pacific during the year of El Niño conditions was 700 million metric tons of carbon less than the previous year. This is equivalent to half of the United States' total annual carbon dioxide emissions from fossil fuel burning.

SeaWiFS images of the 1997-98 El Niño are available at: http://svs.gsfc.nasa.gov/imagewall/el_nino/el_nino_impact.html



Education Update

— Nahid Khazenie (nkhazeni@hq.nasa.gov), NASA Headquarters, Washington, DC
— Steve Graham (steven.m.graham.2@gsfc.nasa.gov), Raytheon ITSS

2000 S'COOL Summer Workshop

NASA Langley Research Center (LARC) is seeking participants for a S'COOL (Students' Cloud Observations Online) Summer Workshop, which will be held July 31 - August 4, 2000 in Hampton, Virginia. Participants will be introduced to the S'COOL program and work cooperatively in developing new materials related to the project. In addition, participating teachers will be provided materials, field trips, and a stipend. Some assistance will be offered for transportation, room and board for participants out of commuting distance to LARC. The offer is available to teachers of grades 3-9 from the following states: Virginia, North Carolina, South Carolina, Kentucky, and West Virginia.

Interested teachers may contact: The CERES S'COOL Project, Mail Stop 420, NASA Langley Research Center, Hampton VA 23681-2199; tel. (757) 864-5682; fax: (757) 864-7996; e-mail: scool@larc.nasa.gov; URL: asd-www.larc.nasa.gov/SCOOL/

Earthworks: Earth System Science For Secondary Teachers And Research Scientists

Earthworks is a one-week workshop for new science teachers, which will be held June 18-24, 2000 in Jamestown, Colorado. It is designed primarily for "pre-service"

(not yet licensed) and beginning in-service secondary-science teachers, who are interested or involved in teaching Earth sciences. For the first time this year, the project is also inviting interested scientists from across the U.S. to participate.

The workshop offers an Earth system focus through field research, with much of the time spent outdoors. Teachers and scientists work together in small groups to design and conduct small research projects, building a learning community that is sustained throughout the school year and subsequent years. The workshop provides opportunities for teachers to learn field research techniques and experiment with teaching through guided and free inquiry. For scientists, this is a unique opportunity to enhance teaching skills, share professional knowledge, and contribute to K-12 science education.

The application deadline is April 15, 2000. More information and application forms are available at URL: cires.colorado.edu/~k12/earthworks/, or e-mail: k12@terra.colorado.edu.

Earth Observatory Announcements

The Earth Observatory, URL: earthobservatory.nasa.gov, is a general public Website documenting the data and new science results that come from NASA Earth science research. You can sign up to

receive an email announcement for latest updates by sending an email to major-domo@eodomo.gsfc.nasa.gov, with the following message in the body of the email: "subscribe eo-announce <your email>."

Global Scanner Newsletter

URL: daac.gsfc.nasa.gov/DAAC_DOCS/Newsletter/global_scanner.html

The Winter edition of *The Global Scanner*, the newsletter of the NASA Goddard Space Flight Center's Distributed Active Archive Center (DAAC), is now on the Web. It features a description of the Operations Section of the DAAC together with a review of the NASA Terra satellite's status and a guest editorial by Professor Steve Running on the importance of NASA's Earth Observing System. There is also new information about DAAC products and general Goddard Earth Science (GES) DAAC activities. The GES DAAC's mission is to maximize the investment benefit of the Earth Science Enterprise by providing data and services that enable people to fully realize the scientific, educational, and application potential of global climate data.

Calendar

April 6-9

National Science Teachers Association, National Convention in Orlando, Florida. For more information, see NSTA's Web site at www.nsta.org, or contact NSTA Conventions, 1840 Wilson Blvd., Arlington, VA 22201-3000; tel. (703) 312-9221; e-mail: conventions@nsta.org.

April 9-12

Gulf Of Mexico Symposium, Mobil, Alabama. The Alabama Coastal Foundation in partnership with the Gulf of Mexico Program will host the fourth Gulf of Mexico Symposium. For more information see URL: www.gulfsum.com.

April 11**Passport To Climate And Weather.**

Research to the Rescue! — Airs at 13:00 hours eastern time. For more information, see URL: passporttoknowledge.com/ptk_storm.html.

April 19

Terra Engineering Competition. Final hands-on competition will be held from 9:00 a.m. - 4:00 p.m. at Howard B. Owens Science Center, Greenbelt, Maryland, near NASA's Goddard Space Flight Center. For more information, see the contest at URL: education.gsfc.nasa.gov/Terra/contest.html.

May 6-10

NASA Student Involvement Program (NSIP) National Symposium, Washington, DC. NSIP is a national competition for students in grades 3-12, which includes the following Earth science competitions: *Watching Earth Change* (For grades 5-8, 9-12) and *Earth Systems in My Neighborhood* (for grades 3-4). For more information see URL: www.nsip.net.

May 30 - June 3

Spring American Geophysical Union (AGU) Meeting, Washington, DC. Includes a number of education sessions. You can find meeting information and the session descriptions at the AGU website URL: www.agu.org/meetings/sm00top.html.

June 4 - July 28

Undergraduate Research Internships In Earth System Science — The Center for Hydrology, Soil Climatology, and Remote Sensing's (HSCaRS) Undergraduate Summer Enrichment Program at Alabama A&M University in Huntsville, Alabama provides summer research opportunities for undergraduate minority and women students in Earth System Science. More details on the program can be found at URL: space.hsv.usra.edu/SEP.html/Index.html.

June 5 - August 11

Graduate Student Summer Program In Earth System Science, Goddard Space Flight Center, Greenbelt, Maryland. For more information, see URL: www.gvsp.usra.edu/gssp, or contact GSSP Program Coordinator, Universities Space Research Association, 7501 Forbes Boulevard, Suite 206, Seabrook, MD 20706; e-mail: GSSP@gvsp.usra.edu

June 11 - July 21

Aurora Summer Program For Undergraduate Students, a six-week summer internship program for undergraduate students interested in pursuing a career in Atmospheric Sciences. The program is jointly sponsored by Hampton University's Center for Atmospheric Sciences (CAS) and the NASA Langley Research Center. For more information, see URL: ww2.hamptonu.edu/science/physics/AURORA/index.htm.

June 18-24

Earthworks: Earth System Science For Secondary Teachers And Research Scientists. Earthworks is a one-week workshop for new science teachers, which will be held June 18-24, 2000 in Jamestown, Colorado. The application deadline is April 15, 2000. More information and application forms are available at URL: cires.colorado.edu/~k12/earthworks/, or e-mail k12@terra.colorado.edu.

11-20 July

Interactions And Diversity: Earth System Science And Beyond, Puerto Rico. A workshop for PR and U.S. teachers, conducted by the Integrated Science Multi-use Laboratory (ISMuL) and the Puerto Rico Space Grant Consortium in collaboration with the Pennsylvania Space Grant Consortium. For more information, a copy of the first circular, and an online application form see URL: ismul.uprr.clu.edu/interactions&diversity/webpages/

index.html or contact Ibis L. Aponte-Avellanet, Executive Director ISMuL, Associate Director PRSGC, University of Puerto Rico, Arecibo Campus, Call Box 4010 Arecibo, PR 00614-4010; tel./fax: (787) 817-4611; e-mail: ibis@adam.uprr.pr

July 24-28

IEEE International Geoscience And Remote Sensing Symposium (IGARSS '00), Honolulu, Hawaii. For details on abstract submission and any other information, please visit the conference Web site or contact: Ms. Tammy Stein, 17906 St. Emilion Court, Spring, TX 77379 USA; tel. +1.281.251.6067; fax: +1.281.251.6068; e-mail: tstein@phoenix.net; URL: www.igarss.org.

July 31 - August 4

S'COOL Summer Teacher Workshop, NASA Langley Research Center (LARC) Hampton, Virginia. Participants (teachers of grades 3-9) will be introduced to the Student Cloud Observations Online (S'COOL) program and work cooperatively in developing new materials related to the project. Contact: The CERES S'COOL Project, Mail Stop 420, NASA Langley Research Center, Hampton VA 23681-2199; tel. (757) 864-5682; fax: (757) 864-7996; e-mail: scool@larc.nasa.gov; URL: asd-www.larc.nasa.gov/SCOOOL/

**Errata:**

"The EOS Land Validation Core Sites: background information and current status", Morisette, et al., *Earth Observer*, November December 1999, v.11, n.6, p. 23. Table 1: The latitude, longitude, and elevations for sites 14-21 and 23 were listed incorrectly. Please refer to the following URL for correct and current information for these and all other EOS Land Validation Core Sites, http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/core_sites.html.

EOS Science Calendar

March 28

TES Science Team Meeting, Denver/Boulder. Contact Reinhard Beer, e-mail: reinhard.beer@jpl.nasa.gov, tel. (818) 354-4748.

March 29-31

CHEM Science Team Meeting, Boulder, Colorado. Contact Anne Douglass, e-mail: douglass@persephone.gsfc.nasa.gov

April 11-13

EOS Investigators Working Group Meeting (IWG), Tucson, AZ. Contact Mary Floyd, e-mail: Mfloyd@westover-gb.COM. For logistical and registration information see URL: eospsso.gsfc.nasa.gov/eos_homepage/logreg.html.

May 2-4

CERES Science Team Meeting, Hampton, VA. Contact Joella Hanlon, e-mail: j.p.hanlon@larc.nasa.gov.

May 9-11

Landsat Science Team Meeting, University of Colorado, Boulder, Co. Contact Jeff Masek, e-mail: jmasek@geog.umd.edu.

June 27-30

Fourth International Conference on Direct Broadcast of Earth Observation Data, University of Dundee, Scotland. Contact Nicholas Kirby, e-mail: nekirby@dux.dundee.ac.uk; URL: www.dundee.ac.uk/dcczr/dbconference.htm.

Global Change Calendar

April 4-8

The Association of American Geographers (AAG), Pittsburgh, PA. Contact: (202) 234-1450, e-mail: gaia@aag.org, URL: www.aag.org.

May 1-2

13th Annual Towson University GIS Conference Geographic Visualization: Turning a Sea of Data Into Data You can See, Baltimore, MD. Contact Jay Morgan, tel. (410) 830-2964, e-mail: jmorgan@towson.edu, also see URL: www.towson.edu/cgis.

May 22-26

ASPRS: The Imaging and Geospatial Information Society, 2000 Annual Conference, May 22-26, 2000, Washington, DC. Call for Papers. For abstracts submission see URL: www.asprs.org/dc2000; tel. (410) 208-2855; Fax: (410) 641-8341; e-mail: wboge@aol.com.

May 30-June 3

AGU 2000 Spring Meeting, Washington D.C. Contact: (202) 462-6900; (800) 966-2481; e-mail: meetinginfo@agu.org, URL: www.agu.org.

June 12-14

Sixth Circumpolar Symposium on Remote Sensing of Polar Environments, Yellowknife, Northwest Territories, Canada. E-mail: circumpolar2000@gov.nt.ca, tel. (867) 920-3329, URL: www.gov.nt.ca/RWED/rs/circumpolar2000.

June 22-24

Climate Change Communication International Conference, Kitchner Waterloo, Ontario, Canada. URL: geognt.uwaterloo.ca/c3confer/.

July 16-23

International Society for Photogrammetry & Remote Sensing (ISPRS) 2000, Amsterdam. Call for Abstracts. Contact organizing secretariat, tel. +31 20 50 40 203; Fax: +31 20 50 40 225; e-mail: isprs@congreg.nl.

July 16-23

33rd COSPAR Scientific Assembly, Warsaw, Poland. COSPAR Secretariat, 51, bd.de Montmorencym 75016 Paris, France, tel. (33)-1-45250679; Fax: (33)-1-40509827; e-mail: COSPAR@PARIS7.JUSSIEU.FR.

July 24-28

IEEE 2000 International Geoscience and Remote Sensing Symposium, 20th Anniversary, Hilton Hawaiian Village, Honolulu, Hawaii. Call for Papers. For up-to-date data regarding submissions, access the conference website at URL: www.igarss.org.

July 24-29

International Radiation Symposium (IRS-2000), Saint Petersburg State University, St. Petersburg, Russia. Contact conference coordinator, Evgenia M. Shulgina, St. Petersburg State University, Research Institute of Physics, 1 Ulyanovskaya, 198904, St.

Petersburg, Russia; Fax: +7 (812) 428-72-40; e-mail: Evgenia.Shulgina@pobox.spbu.ru; or shulg@troll.phys.spbu.ru.

August 6-17

31st International Geological Congress & Scientific Exhibits, Rio de Janeiro. Contact Tania Franken, tel. 55 21 537-4338; Fax: 55 21 537-7991, e-mail: geoexpo@fagga.com.br, URL: www.31igc.org.

October 9-11

First International Global Disaster Information Network (GDIN) Information Technology Exposition & Conference, Honolulu, Hawaii. Contact: dehring@erim-int.com, tel. (734) 994-1200, URL: www.erim-int.com/CONF/conf.html.

October 9-12

SPIE's Second International Asia-Pacific Symposium on Remote Sensing of the Atmosphere, Environment, and Space, Sendai, Japan. Contact SPIE, URL: www.spie.org/info/ae/.

October 16-20

ERS-ENVISA Symposium "Looking at our Earth in the New Millenium," Gothenburg, Sweden. Call for Papers. Contact Prof. J. Askne, e-mail: askne@rss.chalmers.se; URL: www.esa.int/sympo2000/.

October 16-20

Ocean Optics XV, Musée Océanographique, Monaco. Contact Trudy Lewis, e-mail: trudy@satlantic.com, tel. (902) 492-4988, Fax: (902) 492-4781, URL: raptor.ocean.dal.ca/~optics.

October 24-26

NARSTO Symposium on Aerosol Science, "Tropospheric Aerosols: Science and Decisions in an International Community," Querétaro, Mexico. Contact: normanm@dri.edu, URL: www.cgenv.com/Narsto.

November 6-8

14th International Conference and Workshops on Applied Geologic Remote Sensing, Las Vegas. Contact: wallman@erim-int.com, URL: www.erim-int.com/CONF/GRS.html.

December 5-8

The Pacific Ocean Remote Sensing Conference (PORSEC-2000), Goa, India. URL: members.tripod.com/~PORSEC2000/.

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Space Administration

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Greenbelt, Maryland 20771

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The Earth Observer

The Earth Observer is published by the EOS Project Science Office, Code 900, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5559, FAX (301) 614-6530, and is available on the World Wide Web at eosps0.gsfc.nasa.gov / or by writing to the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the Global Change meeting calendar should contain location, person to contact, telephone number, and e-mail address. To subscribe to *The Earth Observer*, or to change your mailing address, please call Dave Olsen at (301) 441-4245, send message to dmolsen@pop900.gsfc.nasa.gov, or write to the address above.

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