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In this issue ...

EDITOR'S CORNER

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Following up on my last report of successful launches for the Ice, Cloud, and land Elevation Satellite (ICESat), and the Solar Radiation and Climate Experiment (SORCE), I'm happy to announce that both missions were successfully placed in orbit and have begun to acquire initial data. The Geoscience Laser Altimetry System (GLAS) on ICESat is the first mission of its kind to accurately measure ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics. The SORCE mission will provide important measurements of incoming x-ray, ultraviolet, visible, near-infrared, and total solar radiation to address long-term climate change, natural variability and enhanced climate prediction.

The first steps in activating the GLAS instrument on ICESat were taken on February 20. In a satellite pass over Norway, the laser firing commenced and firing was confirmed in real time with data from the Laser Reference System (LRS). Evaluation of the location of the laser spot was close to the expected result. Confirmation that the 1064 nm (altimetry) return pulse was obtained from the science data packets transmitted to the ground and processed through the Instrument Support Facility/ICESat Science Investigator-Led Processing System (ISF/ISIPS). Return waveforms look good, and it appears that the laser is very close to the boresight.

Normal operations commenced on March 6 for the SORCE mission, when its instruments began making daily solar observations. All instruments are performing exceptionally well, and are collecting solar data daily. The Total Irradiance Monitor (TIM), and Solar Irradiance Monitor (SIM) are both new sensors, and are beginning to provide new and exciting insights into total solar irradiance and spectral solar irradiance respectively. The SOLSTICE and XPS instruments are also performing very well, and initial data agree

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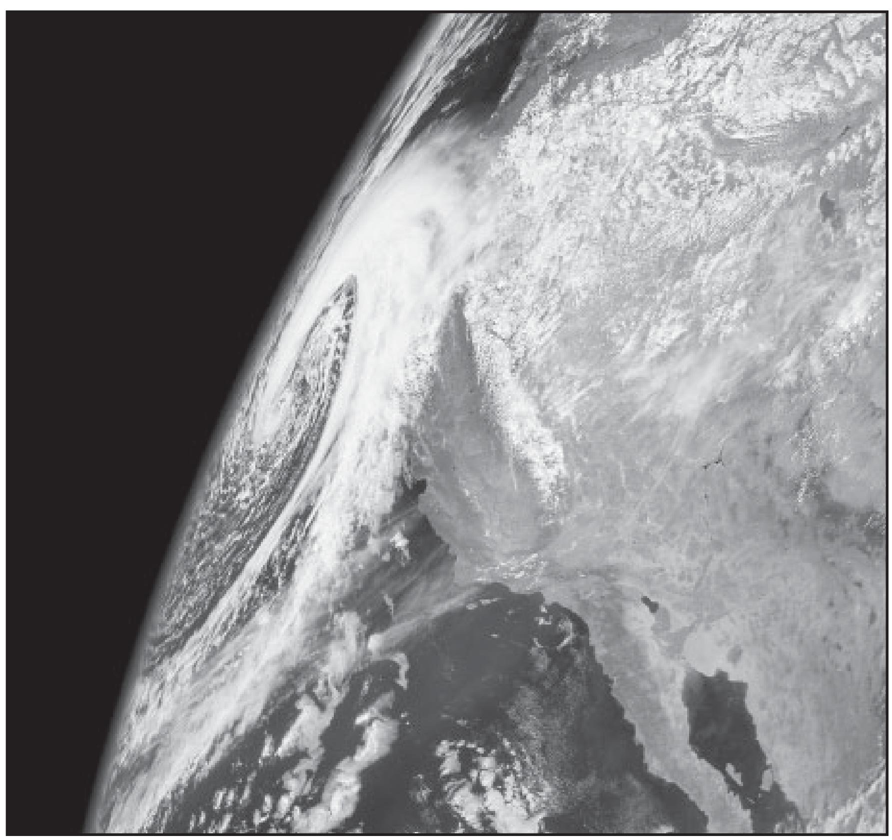
favorably with predecessor instruments such as SOLSTICE on UARS and XPS on the TIMED mission. Data are now being received two times each day through either the ground station at Wallops Island, Virginia or the station at Santiago, Chile.

My sincere thanks and congratulations to the instrument teams, spacecraft teams, operations team, and the project team for their outstanding contributions to these important new EOS missions.

Volume 1 of the EOS Data Products Handbook describing science data products from Terra, the Tropical Rainfall Measuring Mission (TRMM), and the Data Assimilation System (DAS) has been significantly revised. The original document was produced by the Goddard Global Change Data Center in 1997. Many of the data processing systems and resulting data products have changed or have otherwise been enhanced since being described in the original Handbook. ESE program descriptions, mission and data processing overviews, individual data product descriptions, and associated research findings and references have been added or updated. Sample imagery, summary data product tables, and science team contact information have also been updated, and the document has a new graphics layout that matches volume 2 of the Data Products Handbook and the EOS Reference Handbook. Copies can be obtained by contacting the EOS Project Science Office, or on the web at *eos.nasa.gov*.

Lastly, congratulations to George Morrow, who recently assumed responsibilities as the new EOS Program Manager. George replaces Phil Sabelhaus, who has new duties as the Project Manager for the James Webb Space Telescope. George was formerly the Project Manager for Aqua before he left Goddard for a position as Vice President of Jackson and Tull.

The EOS Program Office is the management office for Earth Science Enterprise flight, ground, and science performed at Goddard Space Flight Center, and is responsible for the management and coordination of all projects and mission offices within EOS as well as external coordination and support to NASA's Office of Earth Science (OES) Program Office. I am confident the George will continue the excellent program management EOS has enjoyed under Phil Sabelhaus' guidance.



The Sea-viewing Wide Field-of-View Sensor (SeaWiFS), flying aboard the Orbview-2 satellite, captured this view of a massive low pressure system approaching the northern California coast. Monterey Bay, Point Conception, and Los Angeles are visible along the California coast below the storm. Inland, the thick white vertical stripe is the Sierra Nevada Mountains, still covered in snow. To the right of Los Angeles is a dark irregular feature—the Salton Sea. Below the Salton is a region of irrigated cropland that produces fruits and vegetables throughout the winter. (Image courtesy the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE)

CERES Data Products Workshop

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It was a dark and stormy night…but despite unseasonably wet weather, a crowd of over 60 scientists met with members of the Clouds and the Earth's Radiant Energy System (CERES) Science Team to learn about CERES data products and to discuss their use. The workshop attracted over 25 first-time users of CERES data products. Attendees ranged from a high school student from New Jersey with an interest in volcanic aerosols to veteran climate researchers and modelers from both the United States and overseas.

The two-day workshop, held January 29-30, 2003, in Norfolk, Va., consisted of presentations, distribution of a 5-CD Data Products Sampler set, and many opportunities for discussion. The Langley Atmospheric Sciences Data Center (ASDC) staffed a 5-PC lab to provide hands-on experience in ordering the data products from the ASDC, and in using common visualization tools to access the data in the files. The team timed the workshop to provide maximum benefit to scientists intending to use CERES data in responding to Earth Science NASA Research Announcements released at the end of January 2003. The Data Sampler provides an overview of the data products, representative samples of each data product, the read packages, and their respective quality summaries, as well as other pertinent documentation. It is also useful as a stand-alone introduction to the results of the CERES instrument observations. The sampler provides instructions for obtaining up-to-date versions of the documentation and for ordering data products from the ASDC.

CERES Overview

Bruce Wielicki, the CERES Principal Investigator, described international research efforts on the climate system's energy balance and how the CERES instrument measurements contribute to the understanding of this energy balance. The principal objective of CERES is to produce a highly calibrated, validated data set of solar reflected radiation and Earth emitted radiation at the top of the atmosphere (TOA), within the atmosphere, and at the surface. CERES radiometers are the most accurate and stable instruments ever built for measuring the Earth's radiation budget. CERES is designed to measure solar radiance to an accuracy of less than 1%. Wielicki summarized the overall state of the CERES project and the status of the various resulting data products. Currently, four CERES instruments are flying on the EOS Terra and Aqua spacecrafts with hopes to place another on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) mission. The large, multi-organization CERES Science Team monitors instrument measurements, translates them into various data products, and performs quality assurance. Wielicki summarized the Algorithm Theoretical Basis Documents (ATBDs) and the overall flow of the data from the satellites to the data products (Figure 1). Lastly, he presented an overview of the rather significant scientific impact of the CERES data and its contributions toward improving our understanding of the Earth's climate.

CERES Radiometric Calibration

Kory Priestley described the CERES instrument and the calibration processes. He explained both the pre-flight ground calibration process and the in-orbit calibration for shortwave, longwave window, and total channel measurements. Priestley described the instrument drift over time, and how both drift and spectral response correction factors are developed and applied to yield the Level 1 instrument data products. Scientists derive the ERBE-like data products from the instrument products to ensure continuity of the long-term historical measurement record from the Earth Radiation Budget Experiment (ERBE) instruments.

Imager Cloud and Aerosol Products

Patrick Minnis described how cloud properties directly impact the Earth's radiation budget. Scientists incorporate data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua spacecraft and the Visible Infrared Scanner (VIRS) imager on the Tropical Rainfall Measuring Mission (TRMM) into the CERES footprints to determine cloud properties. Minnis described how the science team derives the cloud properties and applies them using imager measurements and data from other sources. Intercalibration between TRMM/VIRS and Terra/MODIS and comparison to the CERES instrument data permit an assessment of the stability of the results. In addition, the team also performs intercalibrations of CERES data with other sensor data sources such as the VIRS and MODIS reference sources, and with the Geostationary Operational Environmental Satellite (GOES), Advanced Very High Resolution Radiometer (AVHRR), Geostationary Meteorological Satellite, and Meteosat-7 data sources. Intercalibration with Aqua/MODIS will occur in the near future.

TOA Radiative Flux Estimation From CERES Angular Distribution Models

Norman Loeb described the need for angular distribution models (ADMs) and how CERES implements them in computing fluxes for the CERES data products. Scientists use the ADMs to account for the anisotropic nature of reflection to estimate total flux, accounting for, among other things, solar incidence angle and observation angle. The team uses a set of initial models to adjust observations in the Edition 1 series of products. Development of improved models is linked to each instrument, and requires 12 months of observations to gain an understanding of the month-to-month variation in angular distribution, driven by both seasonal cycles and changes in scene type, as well as other influences. Edition 2 data products will reflect these improved ADMs, considering each satellite.

Modelled Surface Fluxes

David Kratz described theoretical models for simplified computation of downwelling clear-sky and all-sky shortwave and longwave surface fluxes. TOA-to-surface parameterizations involving complex radiative transfer models are the key factors in the Single Scanner Footprint (SSF) data products. The scientists use multiple models to ensure high accuracy in the surface fluxes and to maximize the number of footprints where results can be calculated. Highly accurate surface fluxes allow quick testing of time-averaged and spatially interpolated data products. The team validated the surface flux algorithms using ground data from the Atmospheric Radiation Measurement/Southern Great Plains (ARM/SGP) site, Baseline Surface Radiation Network (BSRN), and Climate Monitoring and Diagnostics Laboratory (CMDL) sites, accounting for a variety of climate regimes.

CERES Surface, In-Atmosphere, and TOA Fluxes

Thomas Charlock described the process of computing fluxes at the surface and TOA as well as at three intermediate levels in the atmosphere. The fluxes are delivered via the CERES Surface and Atmospheric Radiation Budget (SARB) data product. Inputs come from the CERES SSF TOA/Surface Fluxes and Clouds Data Product, and data from the European Centre for Medium-Range Weather Forecasts (ECMWF), Model for Atmospheric Transport and Chemistry (MATCH) aerosol assimilation, and National Centers for Environmental Prediction (NCEP). Scientists apply an improved Fu-Liou technique and use a number of other data sources to provide correction factors with a priori uncertainties being assigned to each adjustable parameter. Final corrections compare the computed TOA fluxes and adjusted inputs against the observed TOA fluxes and the initial inputs. Charlock then explained validation efforts to compare with the calculated values and he provided an assessment of the quality of the data products' accuracy.

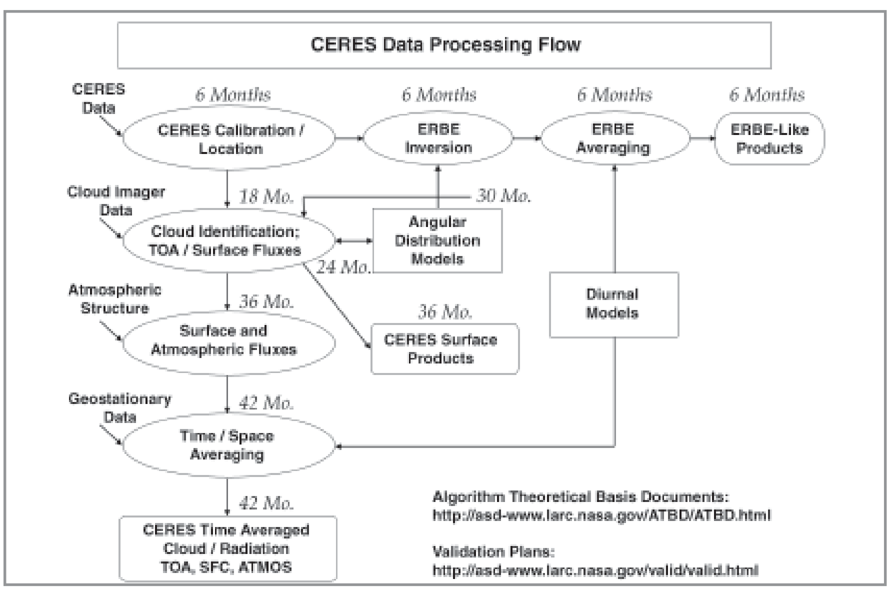


Figure 1 — This chart illustrates the flow of data from the CERES satellite to data products. The planned timeframes for data release are also shown.

CERES Instantaneous Data Products

CERES Data Product	Subsystem Affiliation	TRMM Availability	Terra Availability	Aqua Availability	ERBE-Like Product	TOA and Surface Product	Atmosphere Product
BDS (Bi-Directional Scan)	1.0	Edition 1	Edition 2	Spr '03 Edition 1	X		
ES8 (ERBElike Instantaneous TOA Estimates)	2.0	Edition 2	Edition 2	Spr '03 Edition 1	X		
SSF (Single Scanner Footprint TOA / Surface Fluxes and Clouds)	4.x	Edition 2B	Edition 1A	Spr '03 Beta 1		X	
CRS (Clouds and Radiative Switch)	5.0	Edition 2B	Spr '03 Beta 3	2004 Beta 1			X

CERES Instantaneous Gridded Data Products

CERES Data Product	Subsystem Affiliation	TRMM Availability	Terra Availability	Aqua Availability	ERBE-Like Product	TOA and Surface Product	Atmosphere Product
ES9 (ERBElike Monthly Regional Averages)	3.0	Edition 2	Edition 2	Spr '03 Edition 1	X		
SFC (Monthly Gridded TOA / Surface Fluxes and Clouds)	9.0	Edition 2B	Beta 1	2004 Beta 1		X	
FSW (Monthly Gridded Radiative Fluxes and Clouds)	6.0	Spr '03 Edition 2C	Spr '03 Beta 3	2005 Beta 1			X
SYN (Synoptic Radiative Fluxes and Clouds)	7.0	2003 Beta1	2004 Beta 1	2005 Beta 1			X

CERES Monthly Gridded Average Data Products

CERES Data Product	Subsystem Affiliation	TRMM Availability	Terra Availability	Aqua Availability	ERBE-Like Product	TOA and Surface Product	Atmosphere Product
ES9 (ERBlike Monthly Regional Averages)	3.0	Edition 2	Edition 2	Spr '03 Edition 1	X		
ES4 (ERBlike Monthly Geographical Averages)	3.0	Edition 2	Edition 2	Spr '03 Edition 1	X		
SRBAVG (Monthly TOA / Surface Averages	10.0	Edition 2B	Spr '03 Beta 1	2005 Beta 1		X	
AVG (Monthly regional Radiative Fluxes and Clouds)	8.0	2004 Beta 1	2004 Beta 1	2005 Beta 1			X
ZAVG (Monthly Zonal and Global Radiative Fluxes and Clouds)	8.0	2004 Beta 1	2004 Beta 1	2005 Beta 1			X

Figures 2, 3, 4 — Availability and maturity of CERES data products.

Diurnal Averaging by Merging CERES and Geostationary Data

David Young described the suite of Time Interpolation and Spatial Averaging (TISA) data products and how his team creates and validates them from multiple instruments and data sources. These products include instantaneous spatial averages of the CERES observations, climate-quality monthly and daily means, and global synoptic maps of cloud properties and atmospheric fluxes. Scientists derive new CERES monthly mean products using high-temporal-resolution imager data from geostationary satellites to minimize diurnal sampling errors. All fluxes are tied closely to the CERES observations in order to preserve the CERES calibration stability and to ensure consistency among TOA fluxes, cloud properties, and surface fluxes. Comparisons with high-temporal-resolution surface flux observations validate the Level 3 flux data. Geostationary imager calibration and cloud properties are validated using comparisons with VIRS and MODIS. Scientists test the temporal interpolation algorithms using CERES, TRMM, and Terra data from March 2000.

CERES Documentation Summary

Erika Geier provided an overview of the documentation associated with the various data products and explained the nomenclature associated with them. She described the availability and maturity of the various data products (**Figures 2, 3, 4**). Emphasizing the need to review the Data Product Quality Summary, Geier described how a user can be certain of using the correct version. She also explained the distinction between Beta and Edition data products and emphasized that credible publications cannot be based on Beta products. Documentation can be found at *asd-www.larc. nasa.gov/ceres/docs.html*.

How to Order Data Products and Get User Help

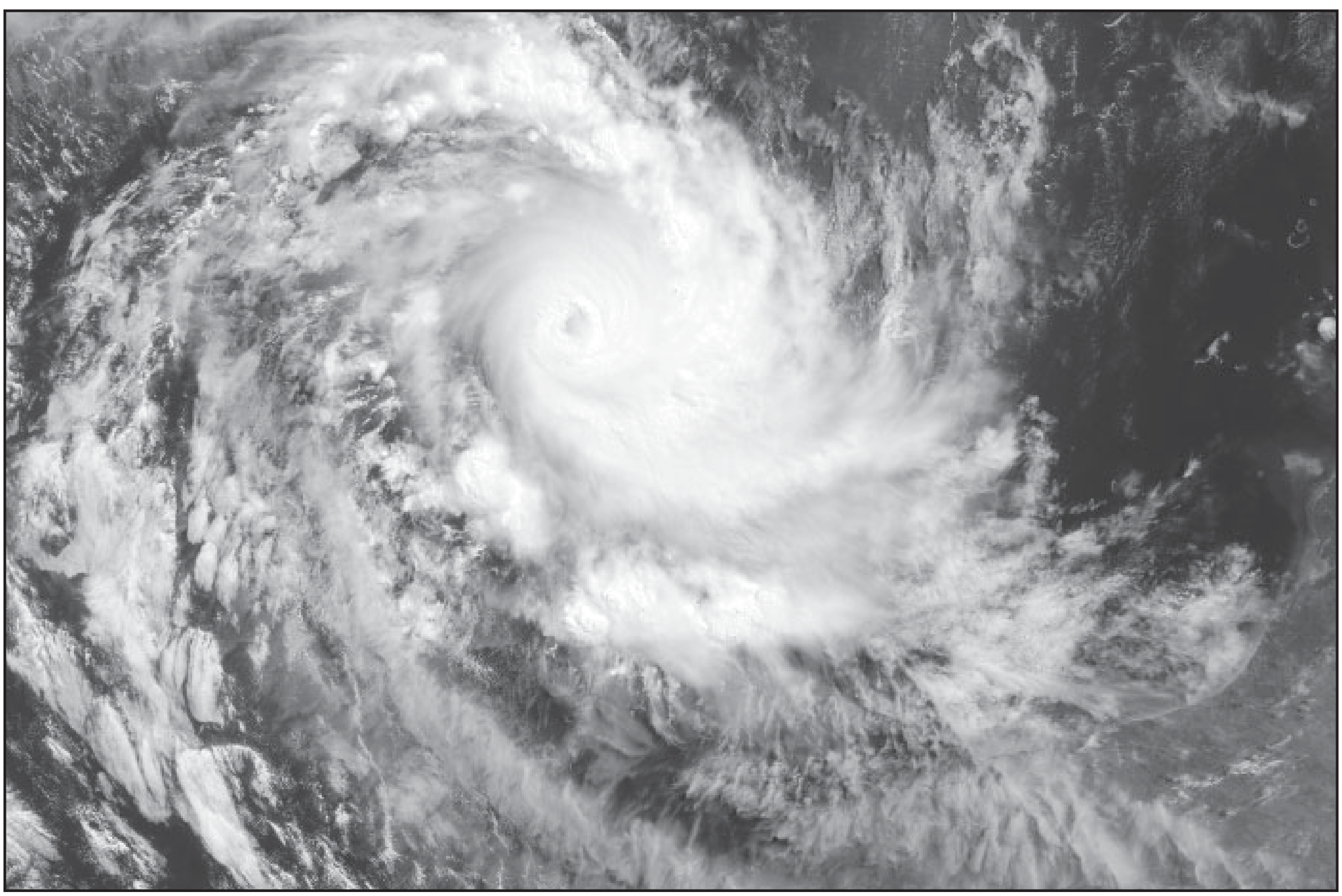
Jim Koziana described the User Services offered at the ASDC, the Web-based ordering tool to obtain CERES data, and other support available from the data center. He also encouraged use of the hands-on laboratory set up at the workshop to resolve any confusion over how to order data products or how to access the data. Attendees reported that this explanation was extremely useful. The public can order data products at *eosweb.larc.nasa.gov*.

Judgment Day: Was the Workshop Useful?

The team closed out the meeting with a survey of the attendees on the usefulness of the CERES Data Products Workshop. Overall, the attendee satisfaction surveys indicated that the workshop was highly beneficial for first-time users. They indicated that the combination of presentations, the hands-on lab, and the CD-set was an extremely effective way to introduce these products. Presentation materials are available from *asd-www.larc.nasa.gov/ceres/DP_wkshop*. Copies of the 5-CD CERES Data Sampler are available from the Langley ASDC (larc@eos.nasa.gov). The Langley ASDC will also distribute Data Samplers at various professional meetings over the next few months.

This high-resolution MODIS image from Terra shows Tropical Cyclone Inigo bearing down on the coast of northwest Australia. At the time this image was taken on April 6, 2003, the winds were around 100 knots (115 mph), down from their maximum speed of 161 mph achieved on April 4. As of April 7, the storm was predicted to continue weakening as it moved toward land, but it could still bring heavy rains to Western Australia and the Northern Territory. In this image, the outer bands of storm clouds have reached the Australian coast and extend northward over the Timor Sea almost all the way to the island of Timor at the top of the image.

(Image courtesy Jeff Schmaltz, MODIS Rapid Response Team, NASA GSFC. Text courtesy *The Earth Observatory*)



Website for Status and Access to EOS Data

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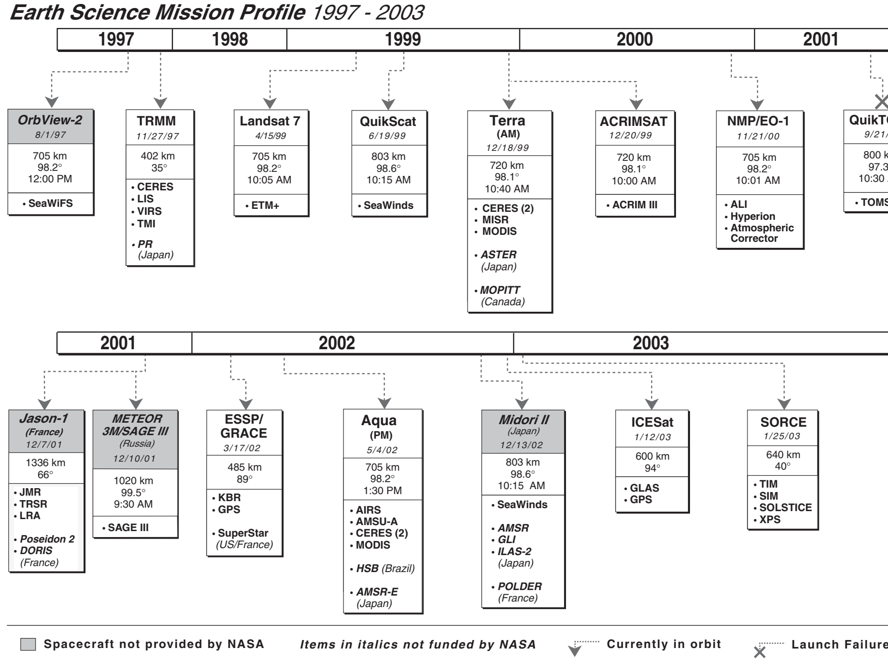
A website has been developed and implemented to provide users and potential users of data from Earth Science Enterprise missions with information on status, location, expected dates of availability, and access to those data. It lists and relates the various names by which the data products have been identified, including Product IDs, Earth Science Data Types (ESDTs), and Algorithm Theoretical Basis Documents (ATBDs). The page provides direct links to specific data product search-and-order interfaces provided by the EOS Data Gateway (EDG) system and the Distributed Active Archive Centers (DAACs); links are also provided to pages for instruments, DAAC User Services, and missions. One can also access general information about platforms, payloads, Principal Investigators, and Project Scientists. The site is not intended to be an additional interface for ordering data, but rather a guide for users to existing search-and-order systems that provide appropriate methods (e.g., geographical, time selection, subsetting, etc.) for data ordering.

Site Organization

The "home page" of the site, *eosdatainfo.gsfc.nasa.gov*, is the hanging chart image depicting EOS missions, shown below, which is updated as needed by the EOS Project Science Office. Clicking on a mission box on the chart takes you to information on that mission (*eosdatainfo.gsfc.nasa.gov/eosdata/terra/platform.html*, e.g., Terra); while clicking on a particular instrument within the mission box takes you directly to information on that instrument and its data. From here one can directly access that instrument's data product page(s).

The data product page(s), organized in matrix form, include the information above plus data validation status definitions, Data Level, Acquisition Date, and Validation Status, where the status is highlighted by color-coding. For cross-referencing purposes, the "Product ID" relates directly to the nomenclature in the "EOS Data Products Handbook." The data product pages are generally all organized the same way, but in a few cases (e.g., MODIS Oceans) there are departures to allow for specific ways in which the instrument teams have organized parameters within their data products. Data status is, of course, evolving, but in all cases the entries are checked by actually going through the search-and-order interfaces to confirm the information in the tables, thus the tables should be accurate at the time of posting.

***Earth Science Mission Profile** 1997 - 2003*



Escape From the Amazon

(For complete text and images, read this story on the Earth Observatory: earthobservatory.nasa.gov/Study/LBA_Escape/)

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In this era of heightened concern about the relationship between the build up of atmospheric carbon dioxide and climate change, scientists are working to itemize all the ways carbon moves between the atmosphere and the elements of Earth's surface, including life, water. and soil. Forests are of particular interest in large part because many nations now manage the forests within their borders, deciding where and when to harvest trees and when to leave the forest alone. Now those decisions are influenced by the role forests play in the global carbon cycle. Forests' ability to take in and sequester carbon during photosynthesis has ceased to be something we accept without thought; the biological services they provide have instead become a product with a market value to be traded between nations like radio parts or soybeans. Just as humans have turned to forests for fuel, food, and shelter for hundreds of thousands of years, we now look to them to help us compensate for the atmospheric excesses of our combustion-engine civilization.

Introduction to the Large-scale Biosphere-Atmosphere Experiment in Amazonia

Whether or not forests will respond as we hope is unclear. Factors other than carbon dioxide availability influence rates of photosynthesis—factors such as water availability and heat stress. In addition, the carbon cycle of a forest involves more than just carbon dioxide uptake because forests burn, decompose, and respire, re-releasing some of their carbon stash back into the atmosphere. We must consider the contribution of many processes to the overall cycle before we can say what future role forests will play in the global carbon cycle or how much we can rely on them to absorb steadily increasing atmospheric carbon dioxide.

Perhaps nowhere on Earth do questions about the role of forests in the carbon cycle need answers more than in the Amazon Rainforest. The largest expanse of tropical forest on Earth, the Amazon covers just 5% of the Earth's land surface (neglecting Antarctica), and yet is responsible for 10% of the net primary productivity of the whole terrestrial biosphere. Once an undisturbed, remote, and inaccessible region, the Amazon is experiencing rapid land-cover change as a consequence of economic development. In the face of such rapid change, scientists are anxious to understand the carbon cycle of the Amazon.

Book-keeping Carbon

Scientists studying the cycle have several sources of information at their disposal. One source is from towers that reach several hundred feet into the top of the forest canopy. Here scientists can measure the flux, or movement, of carbon dioxide into and out of the forest canopy. Another way they retrieve information is by measuring the amount of biomass in the forest. For years, researchers have been monitoring forest plots from the ground, counting trees, measuring them, and sometimes even weighing them to estimate their carbon content. Finally, using mathematical models, scientists sometimes step out from among the trees to take a look at the whole forest. Working backwards from what they know about the global distribution of carbon dioxide in the atmosphere, they try to determine whether the Amazon must be a source of carbon dioxide or a sink, where carbon is stored.

The trouble is that the answer to the question of whether the Amazon is a carbon source or sink seems to depend on where you look for the answer. Jeffrey Richey, a biogeochemist at the School of Oceanography at the University of Washington, has been drawn to the puzzle for more than 20 years. "I guess the real question about the carbon cycle in the Amazon is why tropical rainforests aren't full of monster trees that double in size every year. When we look at the rate of carbon dioxide uptake by forests that is estimated by published results of flux tower measurements, it is a big number—on the order of 3 to 6 tons per hectare each year. That would make the Amazon a huge carbon sink. The problem is, if the trees were taking up that much carbon every year, they would have to be enormous. When we estimate the rate of carbon uptake by looking at the accumulation of carbon in wood and soil, the rates aren't even close to the flux measurements, perhaps more like 1 to 1.5 tons per hectare per year," says Richey.

And then there is the global carbon cycle problem. When the scientists who model the carbon cycle on a global scale work backward from the known concentrations of carbon dioxide in the atmosphere, they find that to make the Amazon carbon budget fit into the global carbon balance—with all the known sources and sinks of carbon—the Amazon is either in near equilibrium with respect to carbon exchange—giving off about as much as it takes in—or is possibly even a source of atmospheric carbon dioxide. Could the Amazon be a source of carbon? Imagining all those trees soaking up carbon dioxide day after day makes that idea seem counter-intuitive, if not downright far-fetched.

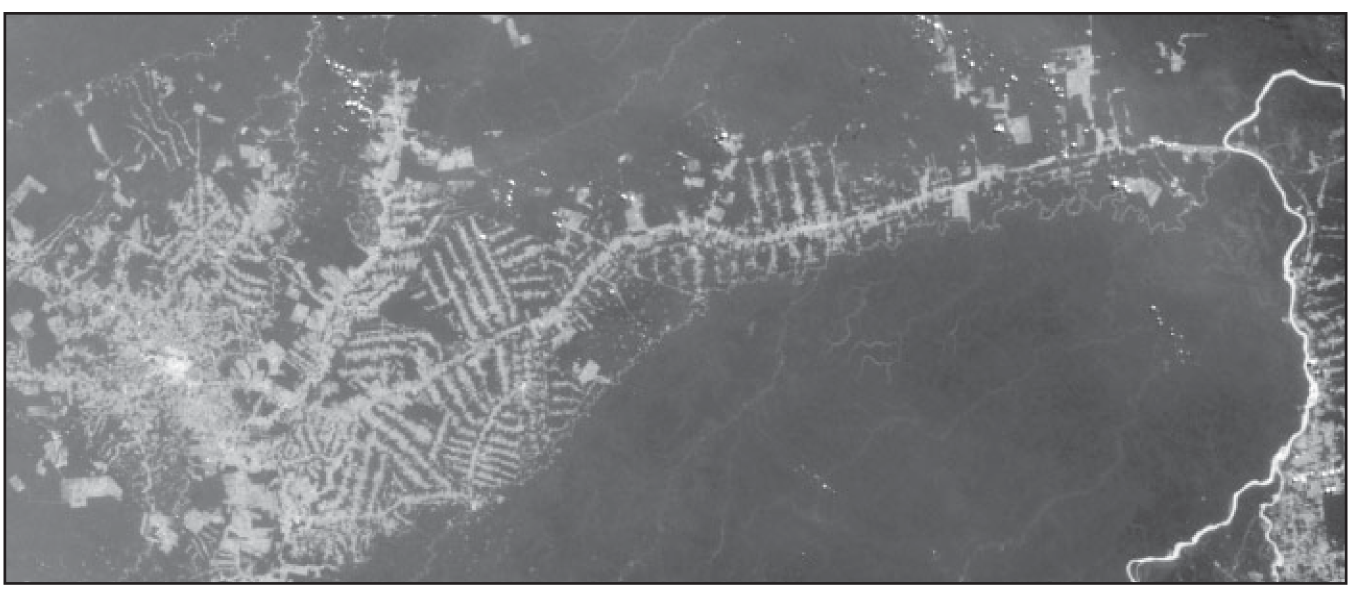
But whether the Amazon is a small sink, as biomass measurements suggest, or a small source, as global models suggest, scientists realize that the ecosystem is clearly not the large sink that the flux tower measurements alone seem to indicate. So where does all that carbon go?

Escaping Carbon

At first glance, the simplest explanation might appear to be deforestation. When forests are cut down or burned, the carbon stored in the forest biomass is released into the atmosphere. Combined with the other processes that carry carbon out of the rainforest ecosystem—decomposition, respiration, soil and sediment run off into the Atlantic—deforestation might be the big source of carbon scientists are seeking. But calculations suggest otherwise. In Brazil alone, deforestation is proceeding at a rate of about 20,000 square kilometers per year as the Amazon is cleared for farming and ranching (Houghton, et al., 2002), but these losses still do not appear to be large enough to offset the large carbon intake measured by the flux towers.

If deforestation wasn't the culprit, then how could scientists account for the apparent discrepancy between how much carbon the flux towers indicated was coming into the forest and the lesser amount of carbon actually contained in the biological material? Researchers had no lack of alternative explanations. Maybe the global models were wrong. Maybe estimates of the rates of deforestation were too low. Maybe there was something wrong with how scientists were collecting the flux tower data. A few scientists, though, did not discount the possibility that the Amazon could be hiding a large, yet-to-be-discovered source of carbon emissions. Richey thought he knew where.

"We had been working in the Amazon for almost 20 years, collecting all kinds of river samples, including measurements of the carbon dioxide dissolved in the water. So as far back as 20 years ago, we were publishing papers saying that the amount of carbon in the waters of the Amazon was greater than that in the air. For years I had been listening to the carbon modelers complaining about the discrepancies in the tropics,



The state of Acre in Brazil, shown in this satellite image taken in 2002, is undergoing rapid deforestation. The lighter areas are recently cleared patches of forest. The image is also hazy due to nearby fires that have been set to clear land.

and I said to myself, 'I know that carbon dioxide is moving out of the water into the atmosphere.' But at that time the scientists doing the carbon modeling didn't talk to the people doing the flux tower measurements, and they didn't talk to those of us who were down on the water."

LBA Brings the Right Scientists Together

But then in 1998, the Brazilian science community, joined by an international team of scientists, launched the Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA). Their aim was to study how Amazonia functions as a regional entity within the larger Earth system and how changes in land use and climate will affect the biological, physical, and chemical functioning of the region's ecosystem. With the Amazon as their laboratory, scientists have been studying climate, atmospheric chemistry, the carbon cycle, nutrient cycling, land surface hydrology and water chemistry, land use and land cover, and the interaction of humans with the landscape.

Richey credits the LBA project for bringing a diverse group of scientists together and encouraging them to speak a common language. It was on a return flight from an LBA conference that Richey began a dialogue with a carbon cycle modeler. He says,"On the plane we started comparing notes. I realized that we had always talked in terms of pressures of carbon dioxide, and they spoke in terms of mass, so many tons of carbon in and out of the ecosystem each year. I realized we would need to put our results into that common language."

Richey knew that what they needed was a grand total: how much total carbon was emitted from water surfaces (a process called evasion) across the Amazon every year. To get a grand total, they required two pieces of information; as many measurements as they could get of the amount of carbon dioxide released by numerous areas within the basin and an estimate of the total surface area covered by water in the Amazon. To come up with these numbers, Richey and his colleagues made use of data sources that ranged from low tech— more than a decade's worth of air and water samples collected from the bows of small fishing boats—to a sophisticated, satellite-based radar.

Using the Right Tools

Richey already had a lot of the river water samples he needed. Between 1982 and 1992, he and his colleagues had periodically gone out on six-week river cruises on a 60-foot, double-decker research boat. In describing those 1,000-kilometer expeditions, Richey says, "The Amazon is almost beyond anything you can imagine. There's this vast life and energy surrounding you. The sky is moving. The river is swirling and churning. There are birds everywhere. Then you get off the big boat and into outboards to go into the narrower floodplains, and you are overwhelmed by the smell of all the vegetation. And all day, there's the pressure of the sun."

In addition to the standard, canned, camp fare you'd expect on a month-long research venture into the depths of the Amazon, Richey says the crew ate delicious local food, especially the fish they bought from local fishermen. The trips were not always idyllic, however. The researchers had one of their scarier moments after being confronted by a local tribe who mistakenly thought the researchers had arrived to take them away and claim a bounty on the tribe offered by drug traffickers. Richey and his colleagues beat a hasty retreat, more than willing to sacrifice a few data points to preserve the peace.

Richey and his colleagues collected more than 1800 river water and air samples within the central Amazon River Basin. In some cases, they used huge winches to haul up samples from deep in the river. In other cases, they captured gas emissions from the water surface using what Richey called "floating dishpans," and described as inverted bowls placed over the water.

The second piece of information Richey needed was a good estimate of just how big an area was covered by water during the year. The Amazon may be perpetually wet, but it is wetter at some times than others. From December to May each year, torrential rains and snow melt from the Andes increase the main river channel's depth 30 to 45 feet, and water backs up in tributaries and inundates forest miles from the main channel. The river and the flooded forests, called várzea in Portuguese, become a giant, slow-moving swamp. Richey needed to know how big.

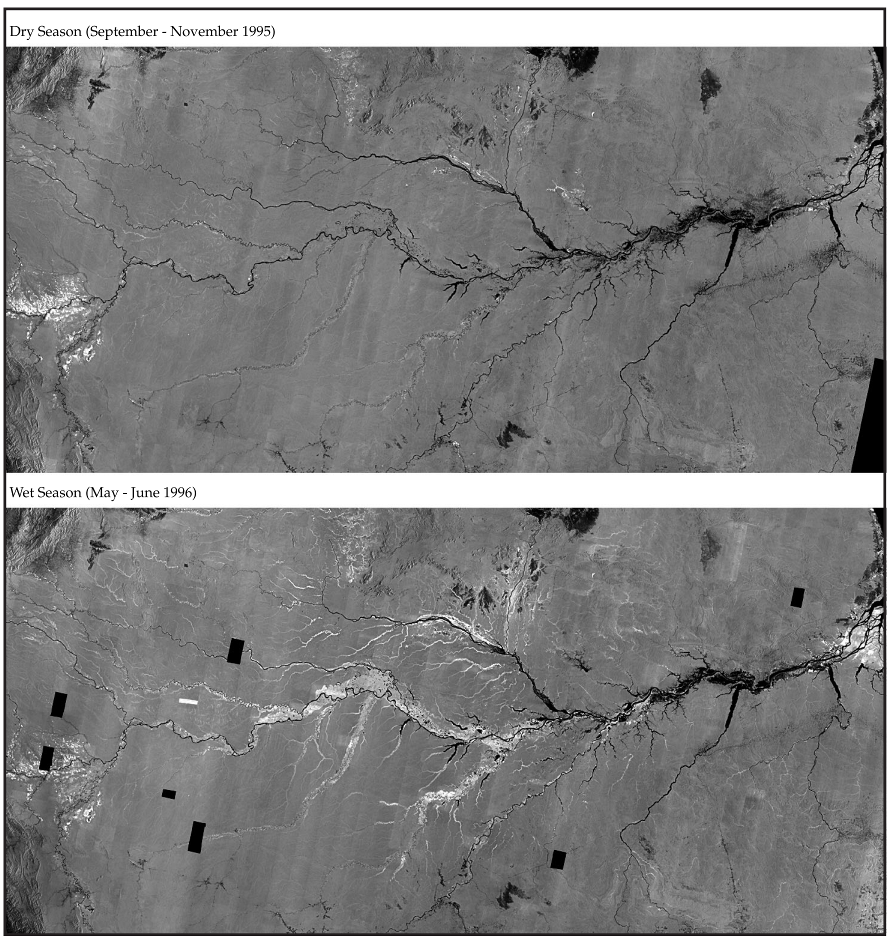
Given the immense area under study, an afternoon trek through the jungle with a camera in hand was out of the question. Satellite mapping was the only real possibility; satellites such as NASA's Landsat series had been mapping the Amazon basin for years in true- and false-color imagery. Optical sensors like those on Landsat, which work like digital cameras, have a serious limitation, however. If there is one thing that you can count on in the Amazon during the wet season, it's rain. At precisely the time of year when

Richey needed imagery to reveal the extent of the flooding, the rain clouds hid the forests from a satellite's view. To map the flooded Amazon forests, Richey needed a remote-sensing device that could see through clouds. He turned to radar.

Seeing Through Clouds

Unlike traditional optical sensors, radar is considered active as opposed to passive remote sensing. Instead of passively recording how much energy is being reflected by or emitted from the Earth as the spacecraft travels overhead, radar works by sending out a pulse of radio waves toward a target and then recording the strength and return time of the signal as it bounces back. That information tells the scientists both how far away the target is and what the surface looks like, since different surfaces will absorb and reflect the pulse in different ways.

Although LBA is a Brazil-led study, it is an international affair. The National Space Development Agency (NASDA) of Japan mapped the Amazon floodplain as part of their Global Rainforest Mapping Project, using radar data collected by the Japanese Earth Resources Satellite (JERS-1). As the satellite mapped tropical rainforests around the globe, different groups around the world became responsible for processing the data and making them available to the scientific community in an easy-to-use format.



Radar maps of the Amazon Basin reveal the seasonally flooded forest. In this pair of images, black represents permanent waterways, dark grey represents forest, and light grey represents flooded areas. (Images based on data provided by the Global Rainforest Mapping Project)

Bruce Chapman is a senior engineer at NASA's Jet Propulsion Laboratory (JPL) in California, which is the organization selected by NASDA to handle the data coming in from South America. Chapman was a principal investigator on the project. "With an optical sensor," he says, "it can take years to create a cloud-free image of the Amazon. Even the supposedly 'cloud-free' image still has some clouds because there are places in the Amazon where the clouds just never go away. Radar wavelengths penetrate the clouds and provide a detailed image of the forests below. The radio waves can even penetrate the forest canopy and reveal the layers of structure within the forest right down to the ground."

It's this ability to see the underlying structure that enabled them to map the extent of the flooding. The water underlying the forest canopy provides a kind of amplification of the returned radar signal. Explains Chapman, "The water underneath the canopy provides something we call a 'double bounce reflection.' This double bounce occurs when the radar waves bounce off two perpendicular structures: the very reflective surface of the water and the tree trunks. This double bounce makes the return signal very bright. When we see that really bright signal in the Amazon, there is a good chance there are partially submerged trees."

Making the Maps

The mapping of the Amazon took place in two phases: one data collection for the dry season and a second one for the wet. The first strip of radar data was obtained on September 27, 1995, over the east coast of South America. The satellite mapping progressed about 75 kilometers westward each day for the next 62 days, with the last strip collected over the west coast in mid-November. Beginning May 4, 1996, the satellite mapped the Amazon in flood. The picture was complete by July 3. Chapman and his team at JPL made the final maps available to the scientific community in March 2001.

Even with the radar data, though, there were limitations. The radar could only see rivers and streams at least 100 meters wide, but hundreds, possibly thousands of small streams branch across the Amazon. "To get those streams," explains Richey, "we had to drill down even further, using Geographic Information Systems (GIS) data sets that had been collected over the years." For the smallest streams they had computer models predict the volume and area based on topographic and geologic features.

Putting Together Maps and Measurements

Despite the aid of satellite data and years of observations, Richey and his colleagues couldn't hope to study the whole Amazon. Instead, they focused their efforts on a large area in the central Amazon basin. They categorized the waters of the 1.77-million-square-kilometer study area into four geographic regions based on the hydrological characteristics: the main Amazon channel, the main channel floodplain, tributaries greater than 100 meters wide, and tributaries less than 100 meters wide. The region was further subdivided into up-, mid- and down-river regions. Based on the carbon dioxide detected in the river samples from each of these categories, they came up with an estimate for the entire study area.

Richey said they had suspected for years that the amount of carbon dioxide evasion could be large, but until they could combine their ground-based measurements with the satellite maps of the total flooded area, they had no hard evidence, no "smoking gun." When the amount of carbon dioxide emitted from the sampled water surfaces was extrapolated to the entire flooded area within the study site, it totaled 120 million grams (264,550 pounds) of carbon per square kilometer per year. A rough estimate for the amount of carbon given off by the entire Amazon River basin was half a gigatonnne of carbon every year—a mass of carbon equivalent to more than 90 million adult elephants!

Says Richey, "When we put our measurements together with the satellite-based flood maps, we got an estimate of carbon dioxide emissions that was greater than 10 times the amount of carbon that washes out to sea in the river outflow. Hydrologists had long thought that the most important role of river systems in the global carbon cycle was in the carbon that flowed out to sea as dissolved organic and inorganic compounds. And now we had an estimate that the carbon dioxide flowing into the atmosphere directly from the river surface was almost 13 times larger than that amount." For the first time, there was solid evidence of a large carbon source within the forest sink.

Identifying the Source of the Source

The carbon in the rivers comes from a number of places. Richey and his colleagues' believe that most of the carbon originates in the non-flooded, upland forests. Accounting for 35 percent of the total, they believe, is forest litter that washes down from highland forests. The litter decomposes, giving off carbon dioxide. Another 25 percent of the carbon comes into the system directly as carbon dioxide when plant and tree roots give off carbon dioxide during respiration. The carbon dioxide becomes dissolved in groundwater that flows into streams and rivers. Another 15 percent comes from carbon-containing compounds that leach out of soil, leaf litter, and other biological matter. Those dissolved organic carbon compounds get metabolized by river life, ultimately returning to the atmosphere as carbon dioxide.

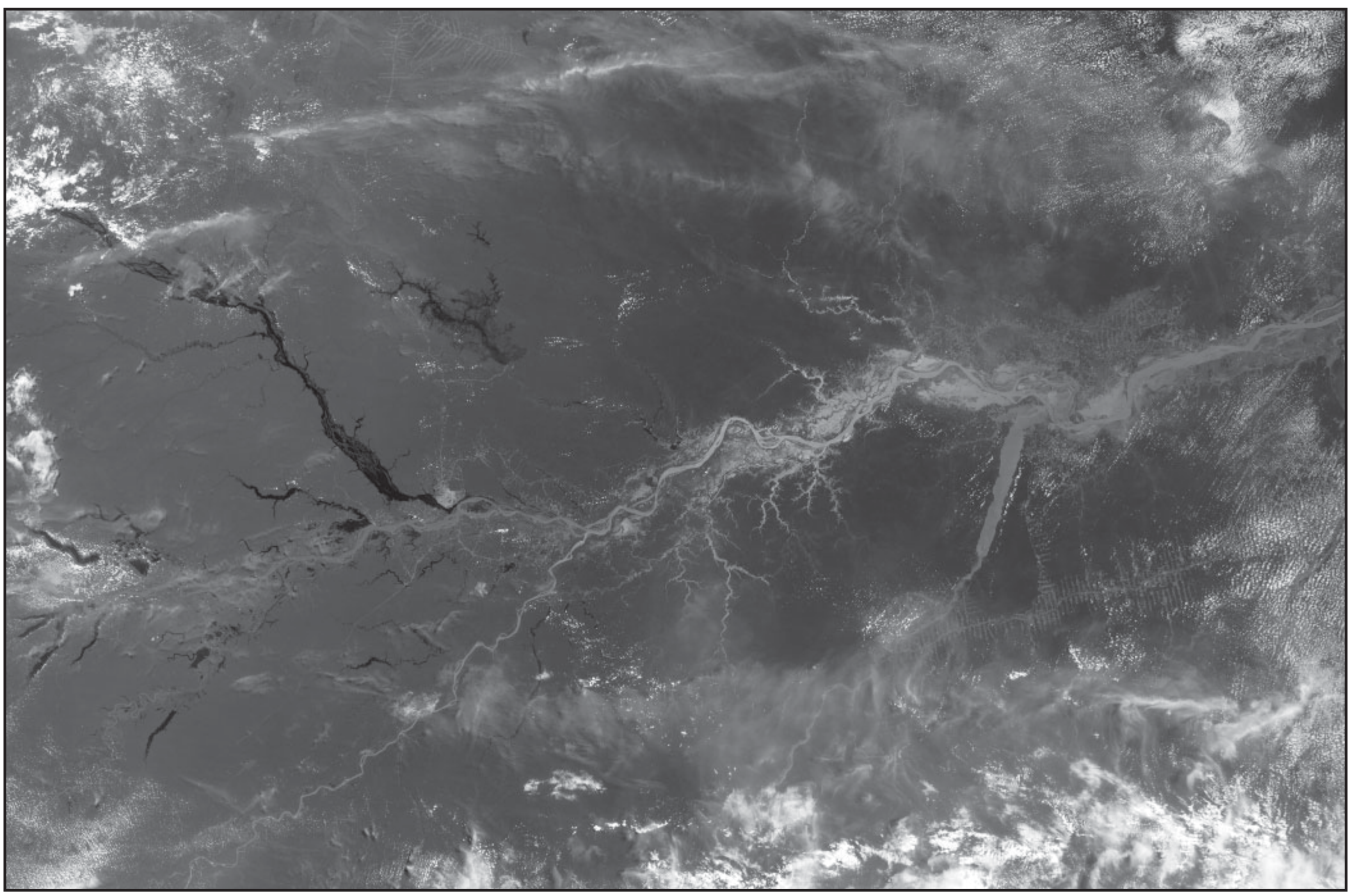
Richey estimates that only about 25% of the carbon given off by the Amazon River and its tributaries actually originates within the river itself, mostly in the form of aquatic vegetation that first fixes carbon dioxide during photosynthesis and then respires some of it back into the water. He admits those numbers are only estimates at this time. Despite the surprising discovery of this large source of carbon emissions, he says, so far the scientific community doesn't seem bothered by the magnitude of his estimate. "There is definitely a sense of 'here is a missing piece' of the tropical carbon budget puzzle."

Answers Produce More Questions

Where that carbon is coming from is more hotly debated. If most of the carbon dioxide released from the Amazon waters comes from carbon originally absorbed by the upland forests and washed down into rivers and streams, as Richey believes, then it would represent a real carbon loss from the ecosystem. But if it turns out the carbon dioxide is produced by vegetation in the river and in the adjacent flooded forests and lakes, rather than the upland forests, then the large emissions only counterbalance a large carbon intake by the aquatic vegetation. The source of the carbon dioxide seeping out of the Amazon waters is the subject of several ongoing studies.

Richey's enthusiasm for the project and his excitement about the results don't seem to have dimmed since the paper was published in the journal Nature in April 2002. "This study was a terrific assemblage of water chemistry data, GIS, theory, remote sensing, and tower dynamics. That's why this was so fun—the integration—all these disciplines coming together to work on a problem." The implication is that the coupling between the land and the atmosphere, and also between the terrestrial Amazon and the aquatic Amazon, is tighter than scientists previously thought.

Those who say that for every question science answers, it generates a dozen more can find evidence in Richey's work. Richey himself is already thinking ahead. He wonders about the effect on this source of carbon from global warming and land-use change. He's also beginning to think globally, and has also begun planning a similar study of the rivers and rainforests near the Mekong River in southeast Asia. And he's not done with the Amazon yet either. Says Richey, "Not all the data we used in this study was gathered specifically to answer this question. Now we have to go back and get better, more detailed measurements, specifically targeted to answering our questions."



The Amazon River, which carries twenty percent of all river water discharged into the planet's oceans, is featured in this Terra MODIS image from September 8, 2002. Surrounding the river, which runs for approximately 4,000 miles (1 mile equals 1.6 kilometers), is the Amazonian rainforest, one of the most ecologically diverse regions on the planet. Fires are scattered around the river, and spidery patterns in the vegetation indicate deforestation. (Image courtesy Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC)

From Space to the Outback

(For complete text and images, read this story on the Earth Observatory: earthobservatory.nasa.gov/Study/Sentinel/)

— Rebecca Lindsey, relindsey@earthlink.net, Science Systems and Applications, Inc.
— Robert Simmon, simmon@climate.gsfc.nasa.gov, Science Systems and Applications, Inc.

As 2002 drew to a close and summer approached in the Southern Hemisphere, parts of eastern and southern Australia were in the midst of one of the worst multi-year droughts on record. Precipitation was at an all-time low, thanks in part to a strong El Niño. Daily temperatures regularly exceeded 100° Fahrenheit (37.7° Celsius) and 70-mile-per-hour (113-kilometer-per hour) winds ripped across the bush. To the west, central Australia was seeing the end of three years of above-average rainfall. In the wet season, pasture grasses were more luxuriant than they had been in 25 years. In the semi-arid environment, such lushness was destined to fade. During the dry season, the verdant fields of grass became millions of acres of tinder. Ironically, these opposite ends of the climate spectrum produced the same result: both the drought-parched landscapes of the southeast and the well-watered central portion of the country ended up in flames.

More than 500,000 square kilometers (123.6 million acres)—70% of the arid zone of Australia's Northern Territory—burned in Central Australia between 2000 and 2002, as did large areas of the arid regions of South Australia and Western Australia. Fires threatened homesteads and devastated pasture, fences, and bores (artesian wells). In southeast Australia, fires exploded at the New South Wales-Victoria border in the Great Dividing Range and Snowy Mountains and grew in all directions. The fires encroached on dozens of communities and blazed through the natural bush corridors of Australia's capital, Canberra. More than 500 homes were destroyed, and with regional cotton, wheat, and other winter crops at roughly half their typical yield due to drought, farmers suffered another blow: thousands of livestock were lost in the fires, and millions of acres of forest, rangeland, and tree plantations were scorched.

This year's devastating fire season is an echo of the 2001-02 season that climaxed in the bush on the outskirts of Sydney and drew international attention once again to the city that had hosted the 2000 Summer Olympics. In the aftermath of that season, Australian scientists and government agencies developed a new fire monitoring system that uses observations from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on the Terra and Aqua satellites to identify fires in remote locations in Australia. The system provides a big-picture perspective of fires across the country and helps fire emergency agencies allocate resources to the areas where they are needed most. In remote areas, MODIS data are even being used to map large fire perimeters and monitor fire movement and growth.

Sentinel On Guard for Australian Fires

Called Sentinel Hotspots, the fire mapping system uses a special capability of the MODIS instruments by which they continuously broadcast their observations of the Earth in "real time." Anyone with the right equipment can capture this radio signal as the spacecraft passes over-head, seeing exactly what MODIS sees within seconds of collection. This feature is known as MODIS direct broadcast, and receiving stations have sprung up all over the world to take advantage of this unique capability.

The Australians harness the MODIS direct broadcast signal at three receiving stations: one near Alice Springs in central Australia, one in Perth, on the southwest coast, and one in Hobart, in southern Tasmania. The advantages of MODIS Direct Broadcast observations captured multi-agency attention. The Alice Springs and Hobart Facilities are operated by the remote-sensing division of Geosciences Australia (the Australian version of the United States Geological Survey); the Perth receiving station is run by Geosciences Australia in conjunction with the Department of Land Administration in Western Australia and the Australian Bureau of Meteorology. Another MODIS receiving station is planned for Darwin, on the north-central coast.

The direct broadcast signal includes all of MODIS' observations—all 36 spectral bands (discrete segments of the electromagnetic spectrum ranging from visible to infrared wavelengths of light). Just five minutes of observations create a file that is about 400 megabytes—not something that could be easily sent via the Internet all over the country! For the Sentinel Hotspots project, a dedicated computer at the Alice Springs station analyzes the data stream up to four times in a 24-hour period, scanning for unusually high amounts of thermal and short-wave-infrared radiation detected by MODIS, which indicate possible fires. The computer automatically creates a small file that includes only these "hot spot" locations and in less than an hour of the satellite's overpass, sends it across the continent to the Land and Water Division of Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) in Canberra. Using this simple latitude and longitude information, the hot spots are incorporated into interactive maps that users can create from any Internet Web browser. The maps show important surface features near the fires, such as roads, rivers, topography, and towns.

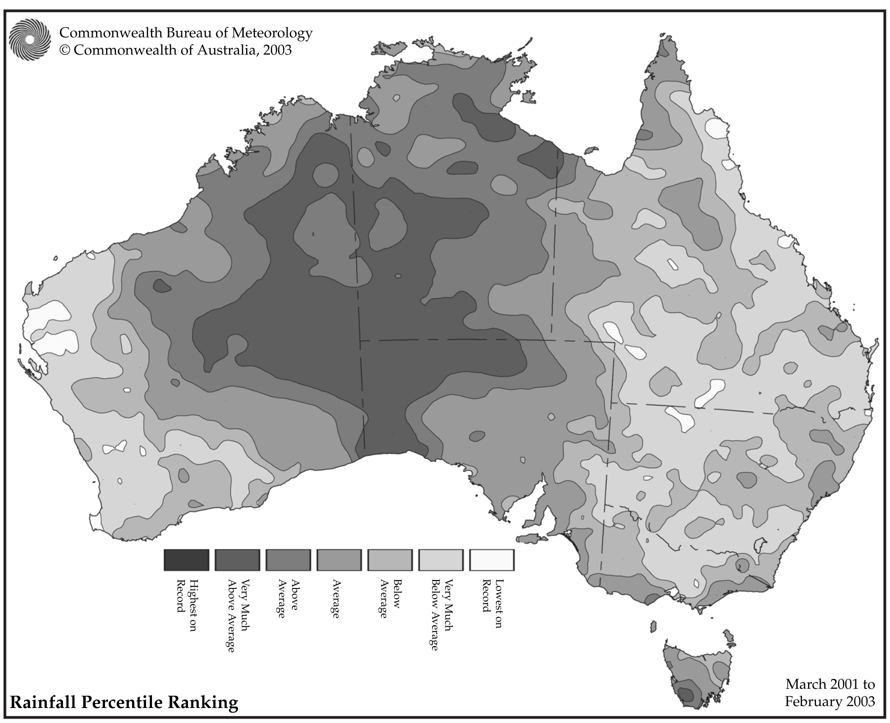
Sentinel Gets Its Start

The Sentinel project has a lot in common with a similar project developed in the United States by scientists at Goddard Space Flight Center (GSFC), the University of Maryland, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture Forest Service. Known as the MODIS Rapid Response Project, it provides near-real-time fire detection from MODIS to the National Interagency Fire Center in Salt Lake City, Utah, where fire management and resource allocation decisions for the U.S. are made.

The parallels between the two projects aren't coincidence. Scientist Chris Justice of NASA-GSFC and the University of Maryland leads the Rapid Response Project, which was designed as a prototype system to demonstrate MODIS' ability to detect active fires all over the world. Through the Global Observations for Forest and Land Cover Dynamics project, the Rapid Response group "had been working to make the international fire science community familiar with the MODIS Rapid Response system and what it could offer to researchers across the world," says Justice. Australia's Sentinel Project was just the kind of endeavor they hoped to motivate.

Among those motivated was Alex Held, a principal research scientist with the land and water division at CSIRO. He's a team leader for a group that specializes in environmental remote sensing. "The idea for our Sentinel Hotspots project started during last year's devastating fires around Sydney, where we began looking at the NASA Rapid Response Website, which provided us next-day, MODIS-derived imagery for areas of Australia. Rather than relying on day-old data," explains Held, "we figured that with the right level of automation, we could use the MODIS direct broadcast data to provide the coordinates for the detected hotspots on a publicly-available Website much faster—within an hour of MODIS data download in Alice Springs."

Held and his colleagues began discussions with the Rapid Response Project and John Guthrie from the U.S. Geological Survey, whose Web-based Geographic Information Systems (GIS) mapping tool, GEOMAC, had incorporated the MODIS fire detections as Held hoped to do with the Sentinel Project. The MODIS Rapid Response Project provided computer software for analyzing the MODIS direct broadcast signal and identifying hot spots and advised the fledgling project on



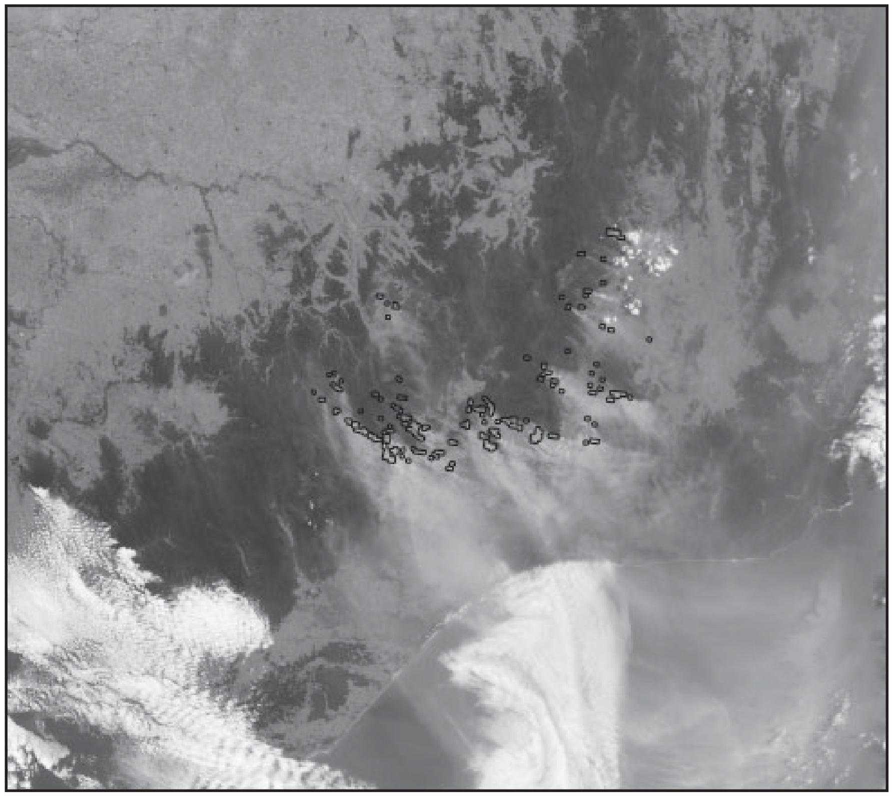
Over the past three years, record rains in central Australia (and the accompanying buildup of pasture grass) and record drought in the east have produced widespread and severe bush fires across the country. In this map, dark gray shows record high rainfall; white shows record low rainfall.

purchasing and installing commercial software packages that would serve as the foundation of Sentinel's Web-based GIS interface. From this international collaboration, and with additional funding from Australia's Defense Imagery and Geospatial Organization, the Sentinel Hotspots project began to materialize.

To assure Sentinel's usefulness, especially to fire and emergency services teams across Australia, the group needed to handle a stumbling block that had been discovered not long after the Australians began receiving MODIS direct broadcast data at the Alice Springs location. The Terra and Aqua satellites sometimes passed over Australia as many as four times each day, in theory providing plenty of opportunity for coverage of the area, but there always seemed to be bits and pieces of the data stream missing. These apparently random periods of data loss, or blackouts, marred an otherwise seamless flow of key fire observations to state agencies.

Among the first users to notice the problem was research scientist Grant Allan from Australia's Northern Territory Bushfires Council. In addition to NOAA hotspot detections that they had been using since 1998, Allan's group had been using MODIS hotspot data provided by the Western Australia Department of Land Administration (DOLA) from the Perth receiving station throughout 2002. DOLA provided simple image maps, listings of fires by geographic location, or data files that could be imported into users' GIS-mapping software applications. DOLA did not provide MODIS true-color imagery, however. As a complement to the MODIS and NOAA AVHRR hotspots from DOLA, Allan had been using the MODIS imagery that the Alice Springs facility was providing from its Web site as a precursor to the Sentinel Hotspots project. "The first MODIS images we had acquired, beginning in April 2002, were unaffected by the data drop outs," Allan says. "At the time, we were able to collect images every second day to delineate the changing perimeters of active fires."

Satellite data from the Moderate Resolution Imaging Spectroradiometer showed both immense plumes of smoke and the location of active fires (black rectangles). Firefighters used the data to allocate resources and map fire perimeters and burn scars, especially in remote areas. This image was acquired February 4, 2003. (Image courtesy MODIS Land Rapid Response Team at NASA GSFC)



According to Allan, the mapping of fire perimeters and burned areas with MODIS imagery provided more information to the Bushfires Council than just the hotspots. "Although we have found that a sequence of hotspots is invaluable to monitor the spread of fires," says Allan, "it is not always possible to compile an accurate picture of the area burned using that information by itself. By April 2002, we were regularly collecting MODIS direct broadcast images from the Alice Springs receiving station, and they had become a significant component of our program in a short amount of time. As our fire season continued across the southern region of the Northern Territory, the unpredictability both of the timing of the drop outs and what area would be affected became frustrating."

Help from the States

In September 2002, Allan e-mailed Justice asking for an explanation of the MODIS blackouts and suggestions for overcoming the problem. "MODIS on Terra regularly stops its direct broadcast as it passes over central Australia, usually for an area extending from 21° to 25° [south latitude]. This causes a major problem for us," he wrote. "We are in the middle of a big fire season and we have come to rely on MODIS images to delineate fire perimeters. If we can't get around the problem in Australia, can we get around it with your help? Is there an opportunity for your system to provide suitable image products for central Australia?"

Feeding MODIS Rapid Response images produced at Goddard Space Flight Center (GSFC) to Allan's group and other fire agencies in Australia was possible, but not ideal. Because the MODIS Rapid Response project is a global fire detection effort, it can't rely on the real-time observations provided by the direct broadcast signal because those can only be collected when the satellite passes over the receiving station. The direct broadcast receiving station at GSFC in Maryland usually picks up real-time observations of the Atlantic Coast of the U.S. and sometimes gets images from as far inland as the Mississippi River, but once the satellite gets out of range, the signal is lost.

The MODIS Rapid Response system instead uses the standard MODIS data feed, in which the satellite stores several hours worth of observations and then passes them off to a nearby geostationary satellite, which relays them to a ground station in the New Mexico desert. This relay yields global coverage, but creates a two- to four-hour lag in posting the images to the web. Justice knew it would be better to find a way to reduce or eliminate the direct broadcast blackout periods when fire-monitoring activities were underway in Australia.

For help in solving the problem, MODIS Rapid Response Leader Chris Justice contacted Bob Kozon, the Flight Operations Director for the Terra spacecraft. Kozon had no trouble identifying the problem. "The MODIS direct broadcast signal transmits using what is called X-band," Kozon explains. "The main radio frequency is about 8.2 gigahertz, but it doesn't transmit exclusively on that frequency. The signal has side lobes that cause the transmission to spill over into the 8.4-gigahertz range or higher."

The 2003 fire season around Canberra, Australia burned more than 2 million acres of land, destroyed more than 500 homes, and claimed at least 4 human lives. In the picture above, flames are destroying the Stromlo Astronomical Observatory. Photograph copyright Simon Bennett.

That spill over created a problem: NASA reserves the 8.4-gigahertz frequency for communicating with its deep space missions, such as the Voyager spacecraft. NASA operates three Deep Space Network stations spaced roughly 120° of longitude apart across the Earth. When Terra flew within radio "earshot" of a Deep Space Network antenna, the MODIS direct broadcast signal had the potential to cause radio frequency interference if NASA were communicating with one of its more far-flung progeny. The problem for Allan and Held and their fire mapping projects was that one of those stations was located just outside of Canberra.

When NASA first identified the potential conflict between the MODIS direct broadcast and the Deep Space Network, the Terra Flight Operations Team and the Radio Frequency Spectrum Management group at NASA's Jet Propulsion Laboratory developed a blackout schedule that would prevent interference while maximizing access to direct broadcast observations for the increasing number of users building receiving stations around the world. "The schedule we worked out took into consideration not just where Terra was in relation to the three Deep Space Network stations—in the Mojave Desert in California, near Madrid, Spain, and Canberra—but also where it was with respect to the actual location of the nine craft presently in deep space," says Kozon. Using this approach, they had reduced the blackouts to a few minutes, sometimes even seconds, each day.

But even these brief blackouts hampered the near-real-time effectiveness and fire tracking abilities of the Bushfires Council and the emerging Sentinel Program. So in November 2002, when the Sentinel Hotspots Project was set to begin delivering data to fire agencies, Held added his voice to those petitioning NASA for a waiver of the mandatory Deep Space Network blackout. Held was optimistic. "I sent an open letter as a concerned CSIRO team leader involved in a public-good project. I had every confidence of a positive response," he says, "given the close relationship NASA has shared with Australia going all the way back to the Apollo moon missions."

On behalf of the Australian direct broadcast users, Kozon asked the Deep Space Network personnel for one last concession. Kozon suggested they leave the MODIS direct broadcast on near the Canberra Deep Space Network so long as there were no scheduled contacts planned between the Canberra station and any spacecraft. Given the possibility that unscheduled contacts might need to be made, the group was initially a little reluctant. Kozon persuaded them with a promise to immediately return to complete blackout if any suspected interference occurred. The results of the first four-week trial period passed without a single incident, and a second waiver was granted.

International Cooperation Yields Success

Both Allan and Held were thrilled with the arrangement. As the fire season in the southern part of Australia began to pick up late in 2002, it gave every indication of becoming at least as severe as the fire season of 2001-02 that initiated the Sentinel Hotspots project. According to Kozon, "Subsequent waivers were easier to get, since by the time the last one was set to expire, the fires in southeast Australia were getting pretty close to the Deep Space Network station in Canberra. Suddenly we all had an interest in keeping the MODIS direct broadcast feed going. We are into our fourth waiver at this point, and we haven't had a single radio frequency interference incident, so it's likely we'll be able to continue helping out."

The waiver ensures that Terra MODIS direct broadcast data can keep Sentinel Hotspots going, even as the project expands to include data from other satellite sources. "The response to Sentinel Hotspots has been overwhelming—much larger than anticipated," says Held. "Over the past few weeks, with the fires around Canberra and the Snowy Mountains, this prototype system has undergone a baptism of fire. We have recorded over 1.6 million [Web] hits on peak days and over 20,000 active users per day creating their own maps. The primary use of the Sentinel information seems to be in the preparation of fire status reports before the 6 a.m. planning meetings that emergency agencies have during such times, but we are also getting some feedback from the public, especially in remote rural areas, who are using our information to help them decide to evacuate their properties or not. The system has filled an important niche in public information, and the media have also been using our information as part of their regular updates on the national fire situation."

Held feels that the new system has brought many people in closer touch with their natural surroundings and has increased awareness of potential environmental threats. "This prototype system has ignited the imagination of many Australians. In a sense Sentinel has become a 'Webcam in the air' for them." In the future Held looks forward to using Sentinel to bring information to Australians not just about fires, but all kinds of threats from the natural environment, such as floods, cyclones, or oil slicks.

The 2003 fire season around Canberra, Australia burned more than 2 million acres of land, destroyed more than 500 homes, and claimed at least 4 human lives. Above, a burned out car sits in a suburb of Canberra. Parts of Canberra's surrounding suburbs were almost leveled in the fires. Photograph copyright Simon Bennett.

Kudos

The National Academy of Engineering (NAE) elected 77 new members and nine foreign associates. We mentioned Michael D. King in the last newsletter but inadvertently omitted the following members of the EOS community who were also honored:

Soroosh Sorooshian, Regents Professor and director, NSF Science and Technology Center, University of Arizona, Tucson, "for the development of flood-forecasting models used worldwide in hydrologic services."

Thomas H. Vonder Haar, University Distinguished Professor of Atmospheric Science and Director, Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, "for fundamental analysis of the Earth's radiation balance and its impact on climate."

The *Earth Observer* Staff apologizes for this oversight and congratulates Drs. Sorooshian and Vonder Haar on their outstanding accomplishment.s.

American Meteorological Society Fellows

The following EOS colleagues were elected 2003 Fellows of the American Meteorological Society:

Dara Entekhabi, Massachusetts Institute of Technology
Lee-Lueng Fu, TOPEX/POSEIDON and Jason-1 Project Scientist, Jet Propulsion Laboratory
George Emmitt, Simpson Weather Associates, Inc.
Ronald Smith, Yale University

American Geophysical Union Fellows

The following EOS colleagues were elected as Fellows of AGU. AGU members who are selected as Fellows have attained an acknowledged eminence in a branch of the geophysical sciences. The number of Fellows selected annually is limited to no more than 0.1% of the AGU membership.

Lee-Lueng Fu, Jet Propulsion Laboratory
Graeme Stephens, Colorado State University
Anne Thompson, NASA Goddard Space Flight Center
M. I. Mishchenko, NASA Goddard Institute for Space Studies

The *Earth Observer* Staff and the entire EOS community congratulate these colleagues on their outstanding accomplishments.

Hurricane Winds Carried Ocean Salt and Plankton Far Inland

— *Elvia H. Thompson, elvia.h.thompson@nasa.gov, NASA Headquarters, Washington*
— *Rob Gutro, rgutro@pop900.gsfc.nasa.gov, NASA Goddard Space Flight Center*

Excerpt from Press Release 03-146

Researchers found surprising evidence of sea salt and frozen plankton in high, cold, cirrus clouds, the remnants of Hurricane Nora, over the U.S. plains states. Although the 1997 hurricane was a strong eastern Pacific storm, her high ice-crystal clouds extended many miles inland, carrying ocean phenomena deep into the U.S. heartland.

Kenneth Sassen of the University of Utah, Salt Lake City, and University of Alaska Fairbanks; **W. Patrick Arnott** of the Desert Research Institute (DRI) in Reno, Nev.; and **David O'C. Starr** of NASA's Goddard Space Flight Center, Greenbelt, Md., co-authored a paper about Hurricane Nora's far-reaching effects. The paper was published in the April 1, 2003, issue of the American Meteorological Society's *Journal of Atmospheric Sciences*.

Scientists were surprised to find what appeared to be frozen plankton in some cirrus crystals collected by research aircraft over Oklahoma, far from the Pacific Ocean. This was the first time examples of microscopic marine life, like plankton, were seen as "nuclei" of ice crystals in the cirrus clouds of a hurricane.

Nora formed off the Panama coast, strengthened as it traveled up the Baja Peninsula, and crossed into California in September 1997. Over the western U.S., Nora deposited a stream of high-cirrus, ice-crystal clouds that created spectacular optical effects, such as arcs and halos, above a broad region including Utah and Oklahoma. That stream of cirrus clouds enabled researchers to analyze growth of ice crystals from different nuclei.

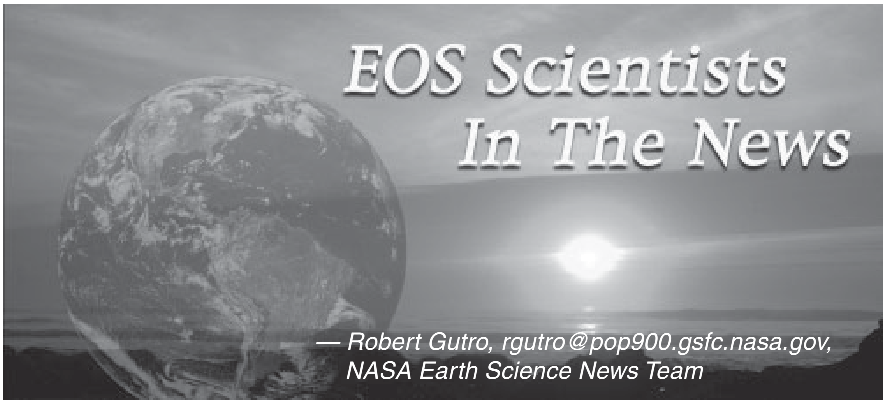
Different nuclei, like sulfate particles, sea salt, and desert dust, affect ice-crystal growth and shape. Torn from the sea surface by strong hurricane winds, sea salt and other particles from evaporated sea spray are carried to the cold upper troposphere in storm updrafts, where the drops freeze and become ice crystals. Plankton, a microscopic organism, is also likely present in the sea spray and is similarly lofted to high levels.

"Understanding how ice crystals grow and what determines their shapes is important in understanding how they interact with sunlight and infrared energy," Starr noted. "These interactions are important processes in the global climate system. They are also critical to sensing cloud properties from space, where NASA uses measurements of the reflected solar radiation to infer cloud physical properties, such as ice-crystal size," he said.

Data were gathered using ground-based remote sensors at the Facility for Atmospheric Remote Sensing in Salt Lake City and at the Clouds and Radiation Testbed in northern Oklahoma. A research aircraft collected particle samples over Oklahoma. Observations from the Geostationary Operational Environmental Satellite 9 (West), launched by NASA and operated by the National Oceanic and Atmospheric Administration, were also used. DRI analyzed the ice crystals collected from Nora.

Scientists were using data generated through the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program. The ARM Program's purpose is to obtain field measurements and developing computer models of the atmosphere. Researchers hope to better understand the processes that control the transfer of solar and thermal infrared energy in the atmosphere, especially in clouds, and at the Earth's surface.

The ARM energy also double-check data from the Moderate Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua satellites. By ensuring that the satellites are recording the same energy reflected and absorbed by clouds from Hurricane Nora as those provided by the ground data in this study, scientists hope to take fewer ground measurements in the future, and enable the satellites to provide the data.



NASA Study Examines Variation of Arctic Ozone Loss, March 31; *Environment News Service* - **Gloria Manney** (NASA JPL) discusses UARS Microwave Limb Sounder data on Arctic ozone loss.

Earthquake Warning in the Ionosphere? Mar.27, *Discovery News* — Russian scientists have been claiming earthquakes are preceded by changes in the ionosphere. **Friedemann Freund** (NASA Ames) said that it's possible electrical fields generated in the ground before earthquakes may affect the ionosphere.

Carbon Storage in Northern Forests Linked to Fire, Mar.24, *Environment News Service* — **Marcy Litvak** (Univ. of Texas at Austin) concluded that most of the net carbon absorption appears to take place 20 to 50 years after a forest fire.

Increasing Solar Trend May Affect Climate, Mar.21, *MSNBC, Space.com, YahooNews* — **Richard Willson** (NASA/GISS and Columbia University) suggests that the amount of radiation the Sun emits during quiet sunspot activity has increased since the 1970s.

Lightning Affects Atmospheric Chemistry, Mar.21, *ScienceDaily, Scientific Germany, UPI* — **Renyi Zhang** (Texas A&M) found summertime lightning can be responsible for up to 90% of nitrogen oxides and increase ozone levels by 30 percent between 3-8 miles above the Earth.

Mt. Pinatubo a Test for Climate, Mar.21, *Environment News Service, Wissenschaftliche Berichte (Scientific Germany)* — **Georgiy Stenchiokov** (Rutgers) linked the 199 eruption of Mt. Pinatubo to a strengthening in Arctic Oscillation for 2 years following.

Throwing Some Cold Water on Next Season's Hopes, March 19; *San Diego Union-Tribune* — **Bill Patzert** (NASA JPL) discusses prospects for long-term drought.

Latest El Nino Wimps Out, March 18; *United Press International*. **El Nino Collapse Lacks Harmony**, March 17; *Space Daily*. **Is Drought Behind Us?**, Feb. 26; *San Diego Union-Tribune*. **Snow Today, Gone Tomorrow**, Feb. 25; *Pasadena Star-News*. **Long Awaited Rain Soaks Southland**, Feb. 12; *Los Angeles Times*. **So Far, El Nino Fails To Take Us By Storm**, Feb. 5; *San Diego Union-Tribune*. **Jet Stream Keeps It Dry**, Feb. 1; *Riverside Press-Enterprise* — **Bill Patzert** (NASA JPL) discusses the current progress of El Nino.

SRTM Data Reveal Impact Crater on Yucatan Peninsula, March 17; *Space News*. **Chicxulub Crater**, March 17; *Aviation Week*. **Killer Crater**, March 15; *Science News*. **New Radar Maps Give Better View of Yucatan Crater**, March 13; *Space.com*. **Feature: Endeavour Mission's Dramatic Find**, March 8; *United Press International*. **Radar Reveals Traces of Killer Crater**, March 6; *MSNBC News* — **Michael Kobrick** (NASA JPL) discusses SRTM imagery of the Chicxulub impact crater in Mexico.

Climate Change Could Bring Severe Weather to California, Mar.7, *Environment News Service* — **Jinwon Kim** (UCLA) climate models suggest increasing carbon dioxide levels may increase the number of extreme precipitation events in the Sierra Nevada Mountains.

Changes in Earth's Rotation Are in the Wind, Mar.6, *Spaceref.com, Physlink, Spacedaily* — **David Salstein** (Atmospheric and Environmental Research, Inc.) found that fluctuations in atmospheric pressure systems may affect how the Earth rotates on its axis.

Minus Snow, What Gives Yoda the Force? Mar.2, *CNN Cable News* — **Jay Zwally** (NASA/GSFC) was interviewed about the changes in Arctic ice from warming.

Winter's Engine? Mar.1, *ABC News* — **David Adamec** (NASA/GSFC) said that North Atlantic Oscillation also affected the climate of the U.S. East coast this past winter.

South Pacific Ocean Temp Affects Snowfall in U.S. West, Feb.28, *ABC News, Scripps Howard News, UPI* — **Jiming Jin** and **Norman Miller** (Berkeley Lab) and **Soroosh Sorooshian** (Univ. of Arizona) used a computer model to understand the link between western U.S. snowfall in winter and spring, with El Nino.

Scientists Find Stardust in Earth's Atmosphere, Feb.27, *Scripps Howard News Service* — **Lindsay Keller** (NASA Johnson) said dust from asteroid fragments and comets resemble those from the beginning of the solar system.

When Lighting Strikes, Feb.20, *ABC News, UPI, Spacedaily.com* - **William Valine** and **Philip Krider** (both Univ. of Arizona) found that during one flash, lightning strikes in 2 or more places 35% of the time.

NASA Scientists Explain California's Recent Gloomy Summers, Feb. 17; *Environmental News Service* — **Bill Patzert** (NASA JPL) discusses a study of fog in Southern California.

NASA Goes On-Line With Extra-Tropical Storm Tracks, Feb.17, *SpaceDaily.com* — **Mark Chandler** (NASA/GISS – Columbia University) and others have created a free online atlas that shows extra-tropical storm tracks between 1961 and 1998.

Scientists in the Snow to Improve Water, Climate Forecasts, Feb.15, *Spaceflight Now, Rocky Mountain News, Denver Post* — The Cold Land Processes Experiment (CLPX), a mission jointly sponsored by NASA's Terrestrial Hydrology, NASA's Earth Observing System Program and NOAA is highlighted.

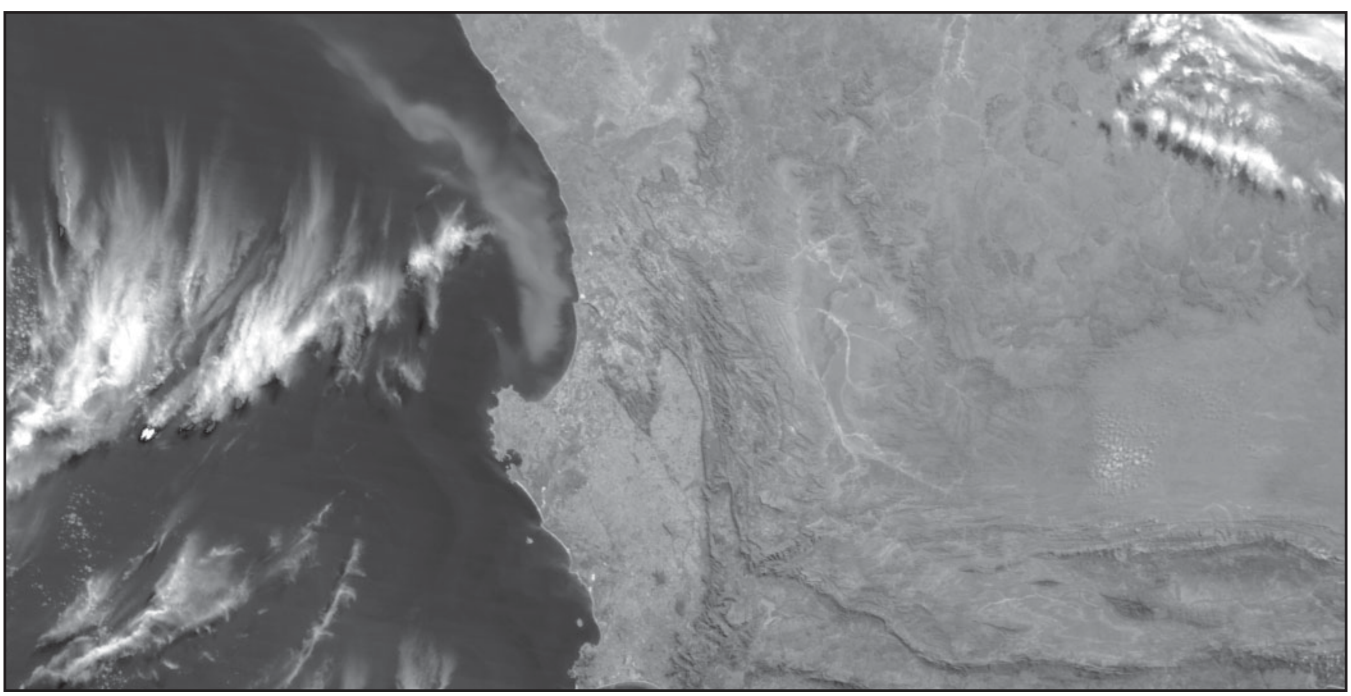
Asian Pollution Cloud Changing Climate, Feb.10, *National Geographic News* — Daniel Jacob (Harvard Univ.) and his team tested for 100 different types of pollutants from China.

Comments After Columbia Accident, Feb.8, *Newswatch This Week; WLOX-TV* — **David Powe** (NASA Stennis) responds to general questions regarding the Columbia accident.

Satellite Sees Earthquake Effects, Feb.7, *Ascribe Wire, UPI, YahooNews* — A NASA satellite is giving scientists such as **Bernard Pinty** (Inst. For Environment and Sustainability – EC) and **David Diner** (NASA JPL) a new perspective on the effects of a major 2001 earthquake in Northern India near the border of Pakistan.

NASA Plane Shadows Snow, Rain Over Sea of Japan, Feb. 6; *Stars and Stripes* — **Simone Tanelli** (NASA JPL) discusses NASA P-3 aircraft instrument study of rain and snow over the Sea of Japan to improve weather forecasting and climate predictions.

On April 10, 2003, the waters off western South Africa were showing swirls of green, while on land, several fires were detected. North of South Africa, it is common for yellowish-green plumes to indicate hydrogen sulfide gas bubbling up from sediments on the sea floor. (As gas wells up, it reacts with oxygen dissolved in the water, producing pure sulfur, which is yellow). Whether this plume is indeed sulfur or simply a normal bloom of marine plants called phytoplankton cannot be determined without more detailed analysis or on-the-ground observations. (Image courtesy Jesse Allen, based on data from the MODIS Rapid Response Team at NASA GSFC)



EOS Science Calendar

May 6 - 8

CERES Science Team Meeting, Norfolk VA. Contact: Shannon Lynch, (757) 864-2458, Email: s.m.lynch@larc.nasa.gov.

May 28-29

Aqua Science Working Group Meeting, Greenbelt, MD. Contact: Claire Parkinson, Email: Claire.L.Parkinson@nasa.gov

June 24-26

Third Annual Earth Science Technology Conference (ESTC). URL: esto.nasa.gov. Contact: Mary Floyd, 301-345-3211 x107, mfloyd@westover-gb.com.

Global Change Calendar

June 2 - 3

16th Annual Geographic Information Sciences Conference, Towson University, Baltimore, MD. Contact John Morgan, tel. (410) 704-2964, Fax: (410) 704-38888, Email: jmorgan@towson.edu, URL: cgis.towson.edu/tugis2003/

June 4 - 6

Oceanology International (OI) Americas, New Orleans, LA. URL: www.oiamericas .com.

June 30 - July 11

International Union of Geodesy and Geophysics 2003, Saporo, Japan. Email: IUGG_service@jamstec.go.jp, URL: www.jamstec.go.jp/jamstec-e/iugg/ index.html.

July 21 - 25

IGARSS 2003, Toulouse, France. Email: grss@ieee.org, URL: www.igarss03.com.

August 30 - September 6

Second International Swiss NCCR Climate Summer School: "Climate Change — Impacts of Terrestrial Ecosystems." Grindelwald, Switzerland. Contact: Kaspar Meuli, Email: nccr-climate@giub.unibe.edu, URL: www.nccr-climate.unibe.ch.

September 8 - 10

Sixth Baiona Workshop on Signal Processing in Communications, Baiona, Spain. Contact Carlos Mosquera, Email: baiona03@baionaworkshop.org, URL: www.baionaworkshop.org

September 23 - 26

Oceans '03, San Diego, CA. Contact: Brock Rosenthal, Email: brock@o-vations.com, Tel: (858) 454 4044, URL: www.o-vations.com.

November 10 - 14

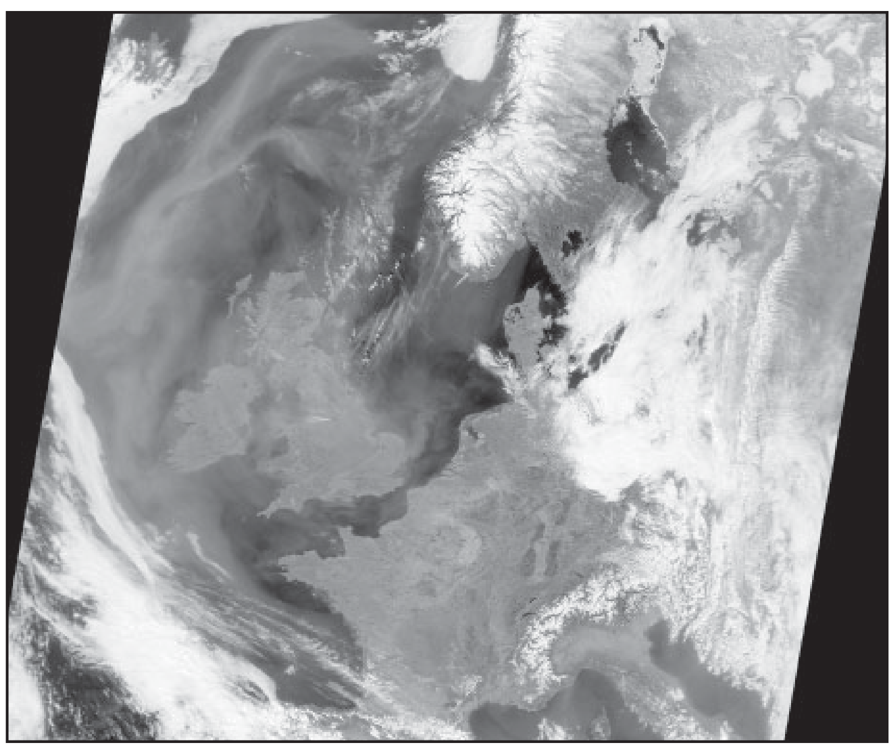
30th International Symposium on Remote Sensing of Environment, Honolulu, HI. Email: isrse@email.arizona.edu, URL: www.symposia.org.

December 9-12

American Geophysical Union (AGU) San Francisco. E-mail: meetinginfo@agu.org URL: www.agu.org/meetings/fm03/

Dust from North Africa mingled with other aerosols in the skies over the United Kingdom (left of center) and Ireland (farther west) on April 18, 2003. In this scene, the dust is more prominent to the north over the Atlantic, where it can be seen as a swirl west of Norway. West of Ireland, the haze is more likely pollution. In the United Kingdom, a few bright plumes of white could be associated with fires.

This image was acquired by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on April 18, 2003. SeaWiFS captured a series of images of the dust, starting on April 16.



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