Earth Observing System

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In this issue ...

EDITOR'S CORNER

Michael King
EOS Senior Project Scientist

I'm pleased to share with you exciting new science discoveries utilizing data from multiple EOS instruments. Recent data comparisons between the Geoscience Laser Altimeter System (GLAS) on ICESat and the Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra show very good agreement in the determination of cloud occurrence, even in Polar regions, especially during the daytime. But not all the news is good to excellent. For example, ICESat has been experiencing problems with its laser altimeter system, and is currently in "safe mode" pending the implementation of a corrective solution. The final report on ICESat's status and recommended resolutions is due out as you read this, which is too late for an additional coincident imaging opportunity with Terra.

The next opportunity for coincident data acquisition with Terra, Aqua, and ICESat is in 2004, but this depends on ICESat's laser lifetime and operational plans. 'Planning is underway for several other multi-platform data sets utilizing data from these and other EOS missions. The EOS formation flying "A-Train" will synchronize orbits and data acquisition from sensors on Aqua, Aura, PARASOL, and three Earth System Science Pathfinder (ESSP) missions. Combined data sets are already utilizing MODIS data from both Terra and Aqua, and the EOS Research Strategy calls for additional emphasis on multi-sensor data analysis. Watch *The Earth Observer* for more information on exciting new science discoveries as new missions become operational.

Despite the anomalies with ICESat's first laser, data quality is excellent and validation is well underway for this and other new EOS missions. In accordance with the evolving laser situation and operational plans, new reference orbits are being calculated for ICESat, and, once generated, will be incorporated into the data processing and ground control systems. Addi-

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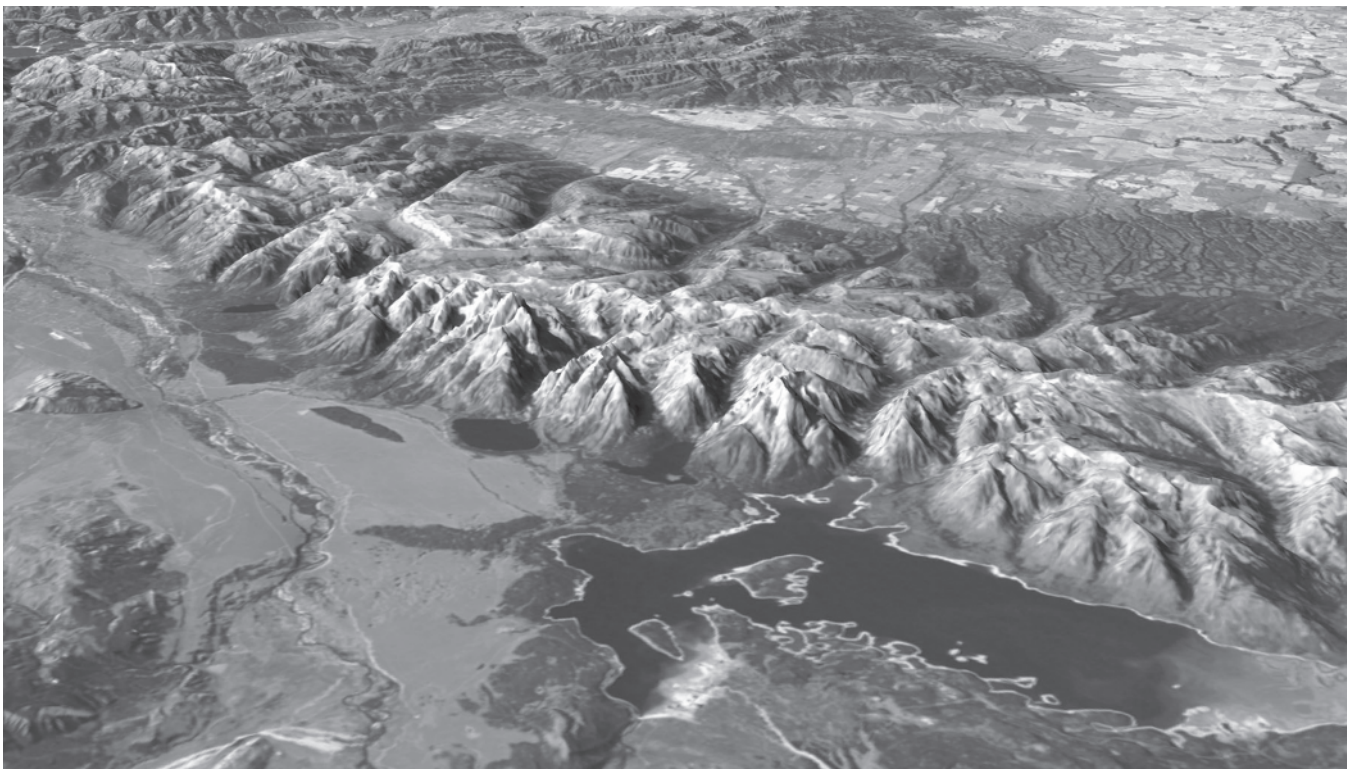
tional validation is being conducted for precise ground track repeats and off nadir pointing and to avoid coincidences with the Hubble Space Telescope.

Aura is scheduled for launch in early 2004, and its Validation Plan involves use of the NASA WB-57 aircraft outfitted with simulator instruments, the Intercontinental Chemical Transport Experiment (INTEX), and field experiments in Costa Rica, Darwin, Australia, and Guam. There will also be coordination with the Convection And Moisture Experiment (CAMEX), and the possible use of unmanned aircraft towards the end of the validation phase.

The Advanced Microwave Scanning Radiometer-EOS (AMSR-E) validation plan includes eight aircraft flights over the Weddell Sea and Bellingshausen Sea in and around Antarctica this September for the purpose of validating AMSR-E's sea ice algorithms. In addition to the P-3B airborne sensors, this experiment includes *in situ* and high-resolution observations from ship as well as Landsat 7, MODIS on Terra and Aqua, Envisat, and Radarsat.

Finally, special sessions on EOS are being planned for the upcoming American Geophysical Union (AGU) meeting in December. The AGU fall meeting in San Francisco is one of the largest multi-disciplinary Earth science meetings in the world, typically attracting over 6,000 attendees from academia, government and the commercial sector. A special hydrology session emphasizing data from Aqua has been accepted, as well as sessions on the solar spectrum and its impact on life on Earth utilizing SORCE data and a Union session on human-induced climate variations linked to urbanization (see *www.agu.org/meetings/fm03*) There will be several other talks, posters, and exhibits highlighting the latest EOS scientific achievements as well. I encourage you to participate in this important meeting, and take advantage of the opportunity to learn more about these exciting EOS activities.



The Grand Teton rises to 13,770 feet (about 4,200 meters), and twelve of the Teton peaks in the range rise above 12,000 feet (3,660 m), more than a mile above the valley below (known as Jackson Hole). They form the youngest section of the Rocky Mountains, yet conversely their uplifting exposes some of the oldest rock formations in North America. The gradual slope on the western side of the peaks reflects the uplifting and tilting of the section of the North American crust shown here. This visualization combines imagery from the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) instrument with elevation data derived from the Shuttle Radar Topography Mission (SRTM) and the United States Geological Survey's Digital Terrain Elevation Data (DTED). The elevation extrusion shown here is to proper scale with no vertical exaggeration. The view shown simulates the view of the park and its immediate surroundings from an elevated camera looking at the park to the south and west. These ETM+ data were acquired on September 23, 2002.

Minutes of the Aqua Science Working Group Meeting, May 28-29, 2003

— Claire L. Parkinson, claire.l.parkinson@nasa.gov, Goddard Space Flight Center
— Moustafa T. Chahine, moustafa.t.chahine@jpl.nasa.gov, Jet Propulsion Laboratory
— Steven Platnick, steven.platnick@nasa.gov, Goddard Space Flight Center

Opening Plenary Session

The May 28-29, 2003, Aqua Science Working Group meeting was opened by Aqua Project Scientist and session chair **Claire Parkinson**, who commented on the striking contrast between the state the Aqua team was in 13 months ago, anxiously awaiting the launch of the Aqua spacecraft, and the state we are in today, with the spacecraft in orbit and a year's worth of data collected. In honor of the one-year anniversary since launch, Parkinson presented the five Aqua science team leaders with plaques thanking them for their leadership and for their many contributions to the Aqua program over the past decade. These plaques went to Moustafa Chahine, Leader of the Science Team for the Atmospheric Infrared Sounder (AIRS), the Advanced Microwave Sounding Unit (AMSU), and the Humidity Sounder for Brazil (HSB), commonly referred to collectively as the AIRS Science Team; Akira Shibata, Leader of the Japanese Science Team for the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), an instrument provided by Japan's National Space Development Agency (NASDA); Roy Spencer, Leader of the U.S. AMSR-E Science Team; Vince Salomonson, Leader of the Moderate Resolution Imaging Spectroradiometer (MODIS) Science Team; and Bruce Wielicki, Leader of the Clouds and the Earth's Radiant Energy System (CERES) Science Team. (The CERES plaque was presented to Norman Loeb for Wielicki, who was unable to attend because of other commitments.) Parkinson also presented a plaque to Bill Guit, the Aqua Mission Director, in recognition of the superb job that Guit and the Mission Operations Team have done in getting the data down from the spacecraft and to the data centers throughout the first year of Aqua data collection.

Parkinson then thanked Al Chang for his many years of service as the Aqua Deputy Project Scientist, lasting through launch, and introduced Steve Platnick as the new Deputy Project Scientist, as of January 1, 2003.

Parkinson showed the first page of a 4-page list of internet links where Aqua data and/or images are available and asked for anyone having additions to the list to contact her, Steve Graham, or Steve Platnick. Next she showed a copy of the recently published Aqua Special Issue of the *IEEE Transactions on Geoscience and Remote Sensing* and pointed to the pile of copies in the back of the room, intended for each of the attendees. This special issue, edited by Parkinson, Chahine, Salomonson, and Chris Kummerow, has 330 pages and 29 articles devoted to the Aqua mission. Copies are available from the EOS Project Science Office (send requests to *graham@pop900.gsfc.nasa.gov*).

Aqua Spacecraft Status

Parkinson introduced Aqua Mission Director **Bill Guit**, who spoke on the Aqua spacecraft and instrument status, data capture, and Level 0 data processing. As explained by Guit, the spacecraft and all subsystems are working well. The ninth and tenth routine drag make-up maneuvers for Aqua, to maintain the desired ground track, were performed on March 19 and April 24. These maneuvers have successfully kept the Aqua ground track well within the original ± 20-km specifications and, in fact, generally within the more stringent ± 10-km specifications desired once the other satellites of the EOS Afternoon Constellation (often referred to as the "A-Train") are launched in 2004.

Guit mentioned a command anomaly that occurred on May 2, 2003, when ground system development team testers accidentally sent 100 commands to the spacecraft. Fortunately, these were commands that did not involve operations (called "no-op commands") and therefore had no impact on spacecraft operations. Nevertheless, Mission Operations personnel have implemented a number of corrective actions to prevent a repeat of this event. Also, on May 12 there was an operator error (unusual in the Aqua experience), resulting in a 12-minute data loss. There are two ongoing spacecraft anomaly investigations, one dealing

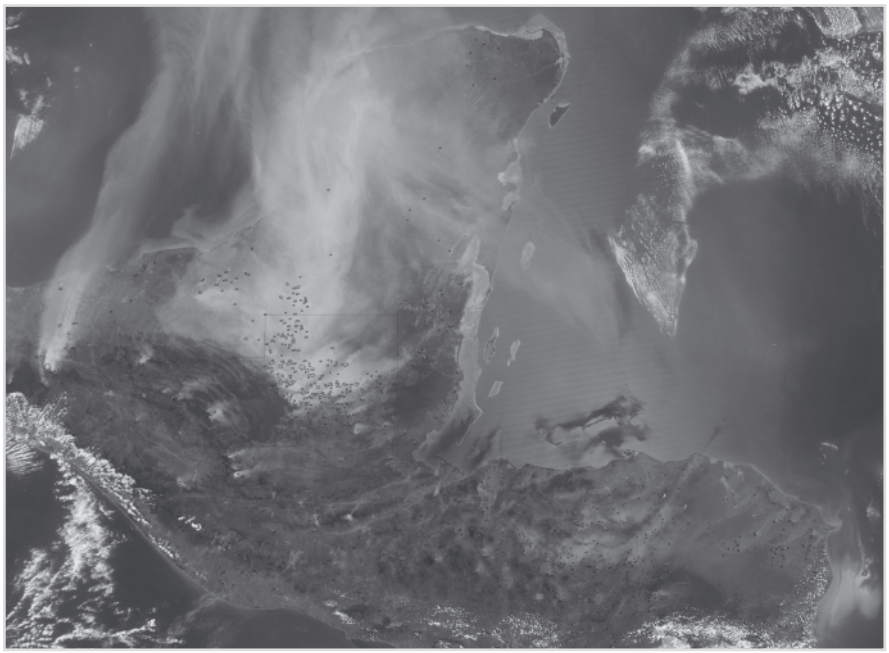
with performance of the propulsion system and the other with the solar array drive assembly (SADA) potentiometer.

With the exception of the HSB, all Aqua instruments are doing well. The HSB had been experiencing minor synchronization problems with a frequency of about twice a week, when on February 5 a greater error was detected, suggesting that the motor had stalled. Guit believes the problem is likely electrical in nature since there is no indication of mechanical difficulties. Nine attempts have been made to resuscitate the HSB, so far without success.

A much lesser problem occurred on March 8 when one of the two CERES instruments (CERES-Aft) temporarily slipped into safe mode. The instrument remained in safe mode for several days but has been operating successfully since then.

Guit emphasized the need for the Aqua scientists to work together with the Mission Operations team, for mutual benefit. For example, Mission Operations personnel are able to make some adjustments in the timing of maneuvers and other operations to avoid interfering with validation campaigns, as long as they are informed beforehand of the timing of these campaigns. It is also important for the scientists to inform Guit and/or Angie Kelly when they observe possible instrument anomalies in the data sets, such as the recently observed non-random noise in the AMSU-A1 Channel 7 performance and the radio-frequency interference in the AMSR-E C-band receiver. The AMSU-A1 Channel 7 noise appears correlated with latitude/orbital position; **Roy Spencer** mentioned that similar problems have been observed with the NOAA 17 AMSU-A1 as well.

Guit concluded by providing the impressive overall data capture rate that the Aqua flight operations team has accomplished: 99.9910791%.



On March 19, 2003, fire in southern Mexico and Central America billowed a cloud of smoke out over the Gulf of Mexico. In this Moderate Resolution Imaging Spectroradiometer (MODIS) image, fires have been marked in gray rectangles, with the highest density occurring in northern Guatemala.

MODIS Science Team Update

The MODIS Science Team Leader **Vince Salomonson** began the MODIS presentation by giving a brief overview of the Terra and Aqua MODIS reprocessing efforts before turning the presentation over to **Shaida Johnston** to present more details on the status of the MODIS data products and the reprocessing. The data products are labeled "beta," "provisional," or "validated," depending on the stage of the validation effort. Beta products are minimally validated, early release products that enable users to gain familiarity with data formats and parameters; provisional products are partially validated and are useful for exploratory and process scientific studies; and validated products are high-quality products with well defined uncertainties, suitable for systematic scientific studies and publication.

Johnston indicated that: (1) Level 1 products for the Aqua MODIS are now all at provisional status; (2) ocean products are all either provisional or, in the case of SST, validated; (3) many of the atmosphere products are also provisional; and (4) the land products include a mixture of provisional and beta products.

MODIS data products are grouped into major "Collections," with the current Aqua MODIS products constituting Collection 3. The upcoming Collection 4 data will incorporate several improvements, including geolocation improvements, band 26 corrections, algorithm alternatives to avoid the use of band 6 (which has several failed detectors) in the cloud mask and snow products, and improvements in the atmospheric profiles. Johnston explained that the MODIS Team is in the

midst of MODIS Collection 4 reprocessing for Terra and will not begin the Aqua Collection 4 reprocessing until the Terra reprocessing is completed, freeing the computers to proceed with Aqua. Current expectations are that the Aqua Collection 4 reprocessing will begin in November 2003 at the earliest. Johnston explained that because reprocessing requires considerable effort, reprocessing is only done when the software changes are considered significant. Salomonson further explained that major science software changes for the MODIS data are quite rare and that minor changes such as metadata changes are considerably more frequent. Johnston proceeded to explain that each time the reprocessing has been done, it was done faster than the previous reprocessings. She anticipates Collection 4 for Aqua to be completed in 2004, Collection 5 in the 2004/2005 time frame, and Collection 6 in the 2006 time frame. Earlier data Collections are deleted about six months after the Collection becomes outdated. The MODIS Science Team hopes to have at least a three-year overlap between Terra and Aqua data.

Japanese AMSR-E Science Team Update

Team Leader **Akira Shibata** gave the overview for the Japanese AMSR-E Science Team, starting by indicating the stability of the instrument and showing plots of the radiometric noise. He then listed the standard data products for the Japanese Team, in each case indicating whether the product is validated, working but not validated, or not yet calibrated. Three of the products were listed as validated: the water vapor product of Takeuchi and the sea surface wind speed (SSW) and sea surface temperature (SST) products of Shibata. Products listed as working but not validated were precipitation, sea ice, and snow. Soil moisture is expected to be calibrated by the end of 2003.

Shibata showed charts for water vapor validation under clear and cloudy conditions, followed by charts on SST and SSW validation. Major field experiments have included a Wakasa Bay snowfall experiment in the winter of 2003, Mongolian soil moisture experiments, radiometer observations on small islands, and rain gauge observations around an Ishigaki radar. The Wakasa Bay experiment involved the NASA P-3B aircraft as well as Japanese aircraft, ship, and ground observations. Ground measurements in the soil moisture experiment were taken by automatic stations installed systematically within a 120-km x 160-km grid in central Mongolia.

The official AMSR-E Level 1 data products are expected to be released to the public soon, following a May 28, 2003, data review at NASDA. Operational transmission should begin in June, and NASDA's geophysical products should be available within the next few months.

Shibata concluded his presentation with four impressive animations of the Aqua AMSR-E and ADEOS II AMSR data, starting with an animation of global, 10-day-averaged AMSR-E SST data for the period June 2002 to May 2003. This was followed by animations of precipitation from ADEOS II AMSR data for a typhoon in 2003, sea ice from AMSR-E data for the period June 2002 to January 2003, and a Ross Sea iceberg from AMSR-E data for the period June 2002 to May 2003.

U.S. AMSR-E Science Team Update

Roy Spencer, the U.S. AMSR-E Science Team Leader, began his Team's presentation by indicating how pleased he is with the success of the AMSR-E so far. He then turned the presentation over to **Elena Lobl**, the Science Team Coordinator. Lobl presented a timeline of the planned public release of AMSR-E data products, beginning with the expected initial release of calibrated Level 1 data by the Japanese in June 2003. Team member Frank Wentz's group will need about 3 months after receiving the calibrated Level 1 data before beginning the release of Level 2A products in September 2003. Initial release of Level 2B and Level 3 AMSR-E products is expected in March 2004. In the meantime, near-real-time AMSR-E data have been, and will continue to be, available to people doing field campaigns. Prior to the release of the official Japanese calibration, the available data have incorporated a preliminary calibration devised by Frank Wentz.

Lobl gave an overview of the impressive, wide-ranging AMSR-E validation program. This program began in 2003 with a January/February precipitation campaign over Wakasa Bay and surrounding land areas, followed in February by a sea ice campaign in the Sea of Okhotsk. These campaigns used a heavily instrumented NASA P-3B aircraft, with an AMSR simulator (the Polarimetric Scanning Radiometer, or PSR), a 183/220 GHz radiometer, a 21/37 GHz upward viewing radiometer, a 2-frequency precipitation radar, a cloud radar, Langley Research Center 's Turbulent Air Motion Measurement System (TAMMS), an infrared radiometer, and a digital camera, all of which performed successfully. The Wakasa Bay campaign also included two Japanese C-band dual-polarized Doppler radars, Japanese ground- and ship-based observations, including

radiosondes, and a Japanese Gulfstream II aircraft with cloud physics payload. Weather conditions allowed nearly all types of extra-tropical precipitation to be measured over both water and land, and approximately 60 hours of science flights were successfully completed. The validation data are expected to be released in full by the end of 2003 and will be archived at the U.S. National Snow and Ice Data Center (NSIDC). Lobl listed 11 specific science investigations expected to be done with the Wakasa Bay validation data set.

Lobl next described Arctic 2003, an aircraft-based validation campaign over the sea ice of the Bering, Beaufort, and Chukchi seas in March 2003. This campaign also used the NASA P-3B aircraft, and it was aimed at validating the three AMSR-E standard sea ice products: sea ice concentration, sea ice temperature, and snow depth on sea ice. Flights were coordinated with surface measurements at Barrow, Alaska, and at an ice camp in the Beaufort Sea. The aircraft portion was coordinated by Don Cavalieri and Thorsten Markus, while Lobl met with teams on the ground and on the ice.

Lobl then described the Cold Land Processes Field Experiment (CLPX), led by Don Cline. This experiment included several field campaigns in Colorado and measurement of a comprehensive range of snow and frozen soil characteristics. Once again the NASA P-3B was involved, along with a NASA DC-8, a NOAA AC690, and ground measurements. The goal was to validate the passive radiometer data products and also to look at active measurements. CLPX has nested study areas, with people digging pits and measuring snow in three regions of northwest Colorado.

Upcoming validation campaigns include, most prominently, Soil Moisture Experiments 2003 (SMEX 03), led by Tom Jackson, and an Antarctic AMSR-E Sea Ice Validation campaign, led by Joey Comiso. The field portion of SMEX 03 begins in June and July, with *in situ* measurements in Oklahoma, Georgia, and Alabama, and continues with a 10-day intensive measurement period in Brazil in September. Ground, aircraft, and satellite measurements will be made to validate AMSR-E soil moisture products for a range of landcover types. SMEX 03 will be followed next year by the SMEX 04 North American Monsoon Experiment (NAME).

The Antarctic AMSR-E Sea Ice Validation campaign will take place August 23 - September 15, 2003, and, like the Arctic2003 campaign, will involve the NASA P-3B aircraft and the primary goal of validating the three AMSR-E standard sea ice products, although this time for the Antarctic ice rather than for the Arctic ice. P-3B flights will be conducted over the Weddell Sea and the Bellingshausen Sea, on opposite sides of the Antarctic Peninsula, and the aircraft measurements will be complemented by ship-based and ground measurements of ice thickness, salinity, and conductivity, and snow temperature, granularity, salinity, and liquid content.

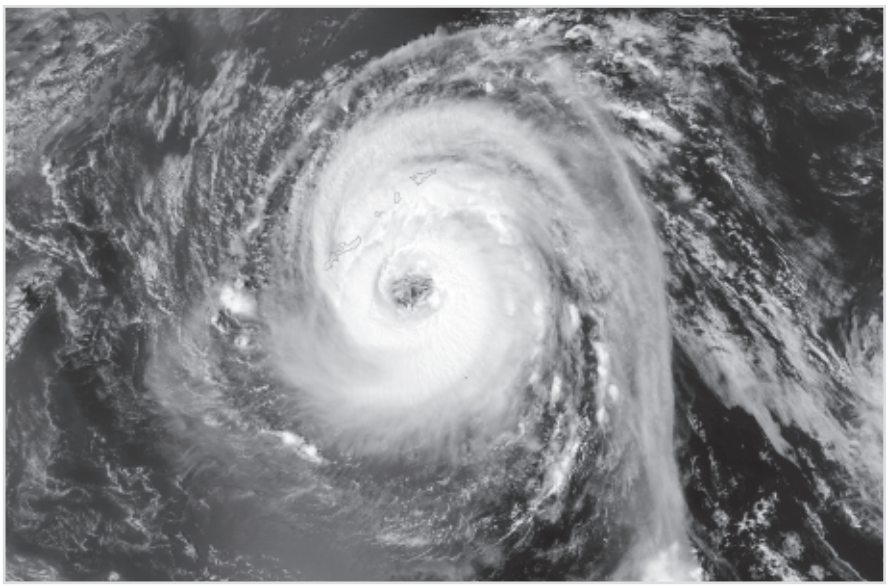
AIRS/AMSU/HSB Science Team Update

AIRS/AMSU/HSB Science Team Leader **Mous Chahine** began the science team presentation with a brief comment explaining that although the currently non-operating HSB is missed, the key requirements of the AIRS/AMSU can still be attained. Prominent among these is the requirement of attaining atmospheric temperature accuracies of 1 K in 1-km layers of the troposphere. Chahine then turned to his colleagues Tom Pagano and George Aumann to present the AIRS/AMSU/HSB (abbreviated AIRS) Science Team update.

Tom Pagano acknowledged the many groups supporting the AIRS program. He then showed radiometric sensitivity curves for AIRS and AMSU and explained that the HSB scanner, which ceased operation on February 5, 2003, appears to have experienced an anomalously high current. The AIRS Team is looking into the documentation that has been received from the HSB manufacturer, in the hopes of finding information that might help the Mission Operations Team to resuscitate the instrument. Fortunately, as Chahine mentioned, the loss of the HSB does not affect the central AIRS/AMSU data products.

Pagano proceeded to comparisons of AIRS data with other data sources. Comparison of the AIRS spectra with spectra from the European Centre for Medium Range Weather Forecasts (ECMWF) looks very good. Comparisons of the AIRS data with GOES 10 data and MODIS data also both show good matches in the Level 1 radiance products. The Level 2 products also look good, and retrieval accuracies are approaching the 1-K-per-1-km goal, as illustrated by Pagano with a plot for a typical day in September 2002. Pagano announced that the first public release of the AIRS data will be in July 2003, at which time both validated and unvalidated data will be released, with flags to indicate whether the product is validated or not and with a validation report accompanying each product. The Project will not restrict access to the data.

There are three distribution modes for the AIRS/AMSU data: through NOAA's National Environmental Satellite Data and Information Service (NESDIS), the Goddard Distributed Active Archive Center (DAAC), and the Direct Broadcast system. NOAA is providing data to numerical weather prediction (NWP) centers within 2 hours and 50 minutes of initial data receipt by NOAA. ECMWF has found that the AIRS/AMSU data have a small, predominantly positive impact on the ECMWF forecasts, and they plan to go operational with incorporating the AIRS/AMSU data sometime this summer. To conclude his portion of the AIRS Team presentation, Pagano reiterated that AIRS and AMSU are in good health, the instrument calibration for AIRS looks good, and the data are being used.



The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard Aqua acquired this image of Typhoon Sinlaku on September 4, 2002. The typhoon passed directly above Japan's Okinawan island chain, generating winds of 145 kph (90 mph) and torrential rains. The typhoon knocked out electricity to tens of thousands of homes, injured 25 residents, and possibly killed five Filipino sailors. The typhoon made its way toward Taiwan, packing sustained winds of 104 miles (167 kilometers) per hour.

George Aumann then presented an AIRS/AMSU/HSB Project Science Assessment for one year after launch. He announced that the AIRS radiometric performance is excellent, as is the AIRS spectral performance. The AIRS SST values match results from the National Centers for Environmental Prediction (NCEP) to within 2 K through most of the globe. Each day there are about 7000 clear footprints from the AIRS. Spectral calibration is extremely important for the non-window channels, with long-term stability critical for the Level 2 products, and the AIRS spectral calibration stability is strong. The AIRS absolute spatial calibration also meets specifications, by being within 3-km of the true position, but there is a position jitter that needs to be explained. The AMSU calibration is similar to that for AMSU-A on NOAA 16, both showing some biases that have an effect in degrading the microwave retrieval. Prior to the February 5 demise of HSB, six months of AIRS, AMSU, HSB data were collected that are now available to evaluate the impact of the HSB 183 GHz channels on moisture retrievals.

Aumann indicated that a major challenge at present for the AIRS Team is to get the Level 2 retrievals working over land. Major algorithm upgrades are being limited to twice a year, as specified in the AIRS Team Leader Proposal. The validation timeline is graduated from tropical day/night ocean to polar day.

Aumann then turned to the use of AIRS/AMSU data in weather forecasting. ECMWF is ingesting 16% of the available AIRS/AMSU data over tropical oceans for trial assimilation. They are only using some channels and only for relatively clear pixels. The expectation is that the impact on the forecasts will be increased as the amount of AIRS data used is increased. Assimilating the AIRS data is a difficult task but should be worth the effort.

Stating that improved weather prediction is only one of the AIRS Team goals, Aumann turned to another key goal, namely the incorporation of AIRS/AMSU data into climate records, using Level 3 products. In view of the large number of AIRS channels, to enable workable data access there is a need to create carefully constructed "decimated" products. There is also the equally important need to familiarize the user community with the data sets.

In conclusion, Aumann stated that the AIRS Team has done an excellent job so far. The current challenges are to develop the software to use the data to full potential, to familiarize the numerical weather prediction (NWP) and climate research communities with the data, and to decimate the data appropriately. During the discussion period, Joel Susskind of the AIRS Team noted that the NWP centers are using radiance data, not the derived standard products.

CERES Science Team Update

Norman Loeb presented the update for the CERES Science Team, reviewing, in turn, results from the Terra deep-space calibration, the status of the Aqua CERES instrument, and recent results from the Terra CERES angular distribution models. The Terra deep-space calibration maneuver was executed flawlessly in March 2003. Results show that the offsets determined prior to the deep-space maneuver were very good, so that the differences produced by incorporating the new results are small. In fact, the changes from pre-launch measurements of scan angle dependent offsets are minimal, and because of the negligible impact to the CERES Earth-Radiation-Budget-Experiment (ERBE)-like products, these are not being reprocessed. The primary benefit of a possible third maneuver (following the March deep-space maneuver and the April lunar maneuver) would be the collection of additional biaxial data. As this would be an important benefit, the CERES Team supports the execution of a third Terra maneuver, with no strong preference regarding whether it be a lunar maneuver or a deep-space one.

Loeb showed preliminary results of an Aqua/Terra inter-calibration over Greenland. Comparing Flight Model 1 (FM1) on Terra and FM4 on Aqua, the shortwave and longwave nighttime agreement is better than 0.4 %, and the longwave daytime agreement is better than 0.7%. Loeb indicated that the Aqua CERES Edition 1 Bi-Directional Scan (BDS) products were available and that the Edition 1 ERBE-like products would be released in June 2003, as indeed occurred.

Loeb then turned to his personal specialty, which is the CERES angular distribution models (ADMs). For climate studies, the radiative fluxes need to be known accurately, and ADMs are needed in order to attain high accuracy levels. The CERES Team creates the ADMs empirically, using MODIS data for scene identification. Loeb explained that the CERES Team is developing ADMs for scene types based on MODIS-derived parameters that have a strong influence on the anisotropy of the Earth's scenes. Loeb showed several sample ADMs for a wide range of scene types. For cloudy scenes, the ADMs are a function of cloud phase, fraction, and optical depth. For clear-land scenes, ADMs are being developed for specific regions on a month-by-month basis. Loeb showed results for one month of clear-land CERES reflectances over 1-degree equal-area regions stratified by solar zenith angle and top-of-the-atmosphere (TOA) Normalized Difference Vegetation Index (NDVI). Loeb compared ADM results for June 2000 clear land shortwave TOA fluxes from the CERES instruments on Terra and the Tropical Rainfall Measuring Mission (TRMM). Shortwave ADMs have also recently been developed for snow and ice conditions, and Loeb showed plots of anisotropic factor versus viewing zenith angle for conditions of fresh snow, permanent snow, and sea ice. He then compared TRMM and Terra ADMs for longwave radiation. Naturally, ADMs developed for the tropics can be expected to show greater errors over the polar regions, especially because of major differences in water vapor amounts. To estimate instantaneous TOA flux errors, CERES ADM-derived TOA fluxes from a scene are compared at different viewing angles using multiangle CERES observations. Plots of instantaneous shortwave TOA flux errors show a significant improvement for the CERES Single Scanner TOA Surface Fluxes (SSF) versus ERBE-like products. In summary, the Terra CERES angular distribution modeling has produced the first set of global ADMs from CERES. The Terra CERES ADMs should be completed in September 2003, while the Aqua ADMs await a longer Aqua data set.

In response to a question from Jim Dodge concerning whether the ADMs vary with time, Loeb explained that temporal changes over a region are accounted for implicitly in the ADMs because the ADMs use MODIS for scene identification. If there are real climatological changes with time in the MODIS-derived properties, the ADMs used to infer CERES TOA fluxes over the region will also change since the ADMs are a function of the MODIS parameters. At the moment, there is a large set of ADMs, for many different situations.

EOS Validation

The EOS Validation Scientist, **David Starr**, presented a brief overview of the current state of the EOS Validation Program. This program supports the High Resolution Transmission (HITRAN) molecular spectroscopic database, the Aerosol Robotic Network (AERONET), the Marine Optical Buoy (MOBY), the Micro-Pulse Lidar Network (MPL-Net), radiosonde launches for validation of AIRS/AMSU/HSB data products, airborne simulators, including a MODIS/ASTER simulator (MASTER), and many field experiments, including the Stratospheric Aerosol and Gas Experiment III (SAGE III) Ozone Loss and Validation Experiment (SOLVE-II) and the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) in 2002,

and seven validation deployments of the NASA P-3B aircraft for AMSR-E in 2003, the golden year of AMSR-E validation. The program has also supported two NASA Research Announcements (NRAs), including one focused in large part on Aqua validation, and will support the North American Monsoon Experiment (NAME) and the participation of AMSR-E team members in it. However, there is an anticipated decrease in validation funding available from the EOS Project Science Office, and this would reduce the amount of support possible in the future.

Jack Kaye, Director of the Office of Earth Science Research Division at NASA Headquarters, clarified the new funding situation from the Headquarters perspective, explaining that the perceived upcoming decrease in validation funding is simply a redistribution of the money and that, in fact, the money for validation has increased. Kaye added that decisions remain to be made on how to distribute the additional money. At that point a question was asked regarding whether a new announcement soliciting validation proposals would be forthcoming. Jim Dodge, EOS Coordinator of the Office of Earth Science Research Division at NASA Headquarters, answered that such an announcement would be unnecessary, as many of the over 600 NRA proposals currently under review include validation efforts.

HSB Substitute

Recognizing that the HSB is currently not operational, **Jim Weinman** brought up the important point that some of the science efforts with the HSB can still be undertaken by using data from the AMSU-B on the NOAA 16 satellite as a substitute for the HSB data. The AMSU-B contains each of the HSB channels and, although the Aqua and NOAA 16 orbits are different, they do have NOAA 16 frequently collecting data over a region within 20 minutes of the Aqua data collection. AIRS Team members were aware of this coincidence, but some of the others in the audience were not.

A Proposed New Data Gateway

David Herring, the NASA Earth Observatory Chief Editor, described a proposed new data gateway called NASA Earth Observations (NEO). NEO will be a central web interface that merges the ability to easily browse and access georeferenced satellite images with the ability to order their matching data files within the DAACs. The goal of NEO is to increase significantly the awareness of, and use of, NASA remote sensing data by NASA's communication partners as well as the "science attentive" public (non-traditional data user communities). The idea originated from collaborations and discussions with several groups interested in easier access to NASA data, including museums in Washington, D.C., New York, and Tokyo, mass media content providers, StormCenter Communications, Inc., and National Geographic. The gateway project is aimed at helping to enable NASA partners and others to gain access to NASA images and data, focusing initially on the data from MODIS, CERES, and AMSR-E. NEO will augment the Earth Observatory web site and be linked to it. The NEO effort will benefit from the existing close working relationship between the Earth Observatory group and the MODIS Rapid Response team that makes MODIS images available within hours. Ideally, the data gateway will provide an interface that enables ready ordering of Earth science data and many advanced help features to assist those who are unfamiliar with obtaining NASA data. A white paper scoping NEO is now in review, and the hope is to have a NEO version 1 available on line within 1-2 years. The process of scaling up NEO to include a full range of Earth Science Enterprise data, model data, and Geographic Information System (GIS) data is expected to begin about June 2005.

The NEO concept addresses key preferences indicated in the responses to a recent survey conducted by the Earth Observatory. In that survey, 85% of the scientist respondents indicated "easy access to data" as the change they would most like to see on the Earth Observatory site. Moreover, roughly two-thirds of lay public respondents said that given easy access to satellite data and easy-to-use software, they would be interested in taking up Earth observations as a hobby. The NEO gateway would enable this ready access.

Mini-Workshop on Aqua Sea Surface Temperatures

After a break for lunch, **Parkinson** briefly introduced the afternoon session, which was a mini-workshop organized by **Mous Chahine** to compare the sea surface temperature (SST) results being obtained by three of the Aqua instruments: the AIRS, MODIS, and AMSR-E. Parkinson indicated that this was the first time that the Aqua Science Working Group was devoting a session to intercomparisons of a single variable, making it an important milestone. She then turned the session over to Chahine.

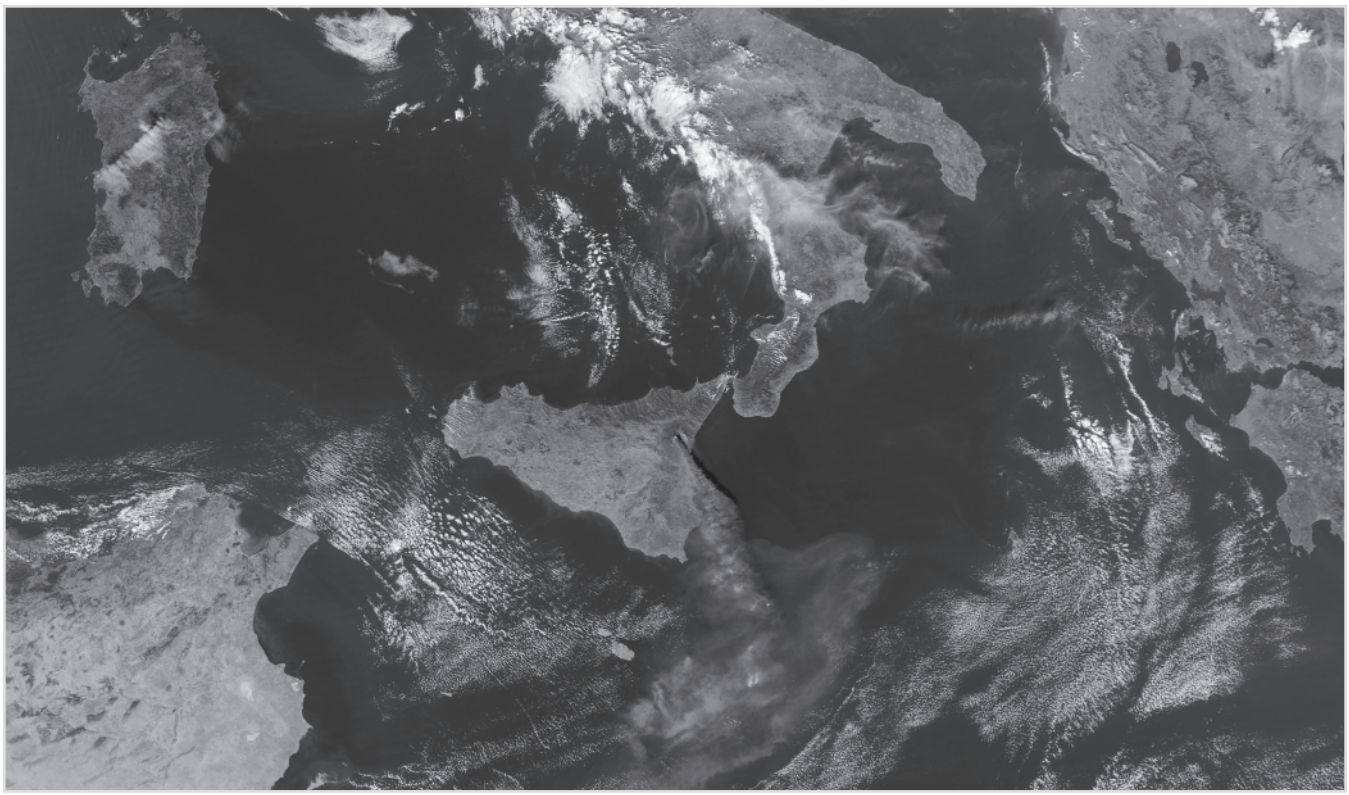
Chahine began by mentioning the three questions that he asked each speaker to address: What are we measuring (skin

temperature, bulk temperature)? How is the accuracy determined? Who are the customers/users of the data? He indicated that the AIRS, MODIS, and AMSR-E are all doing very well and are all being used to derive high-quality products.

MODIS SSTs

Chahine then introduced **Peter Minnett** to present the MODIS SST status and results. Minnett began by mentioning that the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) is producing excellent skin temperature measurements to use in the SST validation efforts. He then identified several conditions essential for accurate infrared measurements of SST from space, the first being that the instrument needs to be well calibrated. The infrared SST measurements, which can only be made in cloud-free conditions, are taken in "windows" where the atmosphere is relatively transparent, although within these windows there are potential problems with varying concentrations of various atmospheric constituents, especially water vapor. This makes the results more complicated in regions with high water vapor amounts, like the tropics. MODIS is extraordinarily complicated, being designed to provide accurate measurements from 0.4 to 14 μm, with at least 10 detectors for each spectral band. There is some risk of crosstalk amongst the channels, although in the window channels used for the SST measurements this seems not to be a problem. The instrumental problems are much less severe with the Aqua MODIS than with the earlier Terra MODIS.

Minnett presented the equation used in the MODIS SST derivation. This equation includes empirical coefficients that are constant both temporally and spatially. There are two approaches for deriving the coefficients: numerical simulations of the brightness temperature measurements, and collocated and contemporaneous matchups with *in situ* measurements. To date, the algorithms based on the matchups with buoys and M-AERI provide more consistent and accurate retrievals. Clouds are also an issue for the infrared measurements, and cloud screening is done separately for daytime and nighttime conditions. For nighttime, the cloud screening involves looking at



On October 28, 2002, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured this image of the ongoing eruption of Europe's largest and most active volcano, Mt. Etna, on the island of Sicily. The volcano's thermal signature was detected by MODIS and is marked with a gray dot. On the northern slopes of the volcano, the thermal signature detected could be a forest fire caused by the eruption. A dense plume of what is likely ash and smoke is streaming southward from the volcano and out over the Mediterranean Sea.

the difference between the SSTs measured at 4 µm and those measured at 11 µm. To date there are 63,433 data points throughout the globe for the MODIS buoy and M-AERI validation data set. The skin temperature can be inferred from the buoy measurements, to an estimated accuracy of 0.15 K (Donlon *et al.*, *J. Climate*, vol. 15, pp. 353-369, 2002).

Minnett showed MODIS statistics for December 2002, plus MODIS monthly SST fields for the three MODIS SST products: daytime SSTs derived from 11 µm data, daytime SSTs derived from 4 µm data, and nighttime SSTs derived from 4 µm data. The nighttime SSTs globally are 0.054 K warmer using the 4 µm data versus using the 11 µm data. Combining Aqua and Terra data helps reduce the obscuration from clouds, as the clouds move, develop and decay. The differences between Terra and Aqua MODIS SSTs are largely explained by the diurnal cycle, although not entirely. Comparing the Aqua MODIS and AMSR-E SSTs, the matches are "extraordinarily" good according to Minnett, who further concluded the following: Most of the instrumental artifacts for the Aqua MODIS are corrected; the empirical atmospheric correction algorithms provide a better product than those derived from first principles; accuracy is established by comparison to buoy and M-AERI measurements (ideally the MODIS team would prefer to use just M-AERI data but these are too few compared to the large buoy data set); and cloud screening requires additional attention (there are plans to use comparisons between Aqua MODIS and AMSR-E SSTs for catching remaining cloud contamination). SST accuracies were presented at this meeting as global accuracies, although eventually the accuracies will be examined regionally also. Surprisingly, the SST accuracies seem to be better in the tropical regions than in the polar regions.

Minnett then provided answers, for the MODIS instruments, to each of an expanded list of questions Chahine had requested that the speakers address. Specifically:

- *What have we learned so far?* A great deal about MODIS, including that the Aqua MODIS is much improved over the Terra MODIS.
- *What are we measuring?* Skin temperature.
- *How much model information is injected?* None.
- *How is accuracy determined?* By using National Institute of Standards and Technology (NIST) traceable M-AERI and numerous buoys.
- *Who are the specific customers/ users for the data?* The research community.
- *What are we trying to achieve that is new or different? What message should we/the EOS deliver to the research community?* MODIS SSTs are at least as good as Advanced Very High Resolution Radiometer (AVHRR) Pathfinder SSTs, can be used in similar types of analyses, and are measured at a finer spatial resolution.
- *Where do we go from here?* Resolve and correct diurnal effects and regional, seasonal biases; create merged infrared and microwave SSTs to overcome cloud issues; provide the wider user community with uniform gridded data.

Parkinson asked if consideration was given to the fact that SSTs underneath clouds might be biased (cooler in daytime than in clear surrounding regions), thereby biasing global averages based on the MODIS SSTs, which tend to be calculated only in relatively clear areas. Minnett acknowledged the difficulty and explained that the M-AERI measurements, which are taken in cloudy as well as clear areas, will be used to help address this issue. He also pointed out that in situations with broken cloud fields, the spacecraft radiometer is not viewing the surface with the same geometry as the solar illumination and therefore does not necessarily view only the sunlit sea surface. Furthermore, in terms of the skin effect, the influence of clouds could be expected to be small, especially in the tropics. Chahine questioned whether the skin surface temperature could be derived to 0.15 K accuracies from the buoy data, precipitating a productive further discussion between Chahine and Minnett.

Japanese AMSR-E SSTs

Akira Shibata presented the SST status and results from the Japanese AMSR-E Science Team. Corrections made by the Japanese team include an atmospheric correction, wind speed correction, wind direction correction, land contamination removal, sun glitter removal, sea ice removal, incident angle correction, and salinity correction. Shibata showed a global image for December 1, 2002, for atmospheric correction for 6.9 GHz vertical polarization. Although the AMSR-E microwave measurements allow SST derivations under most weather conditions, this does not include conditions of precipitating clouds. Shibata then showed a global image of the wind speed correction, followed by an image for the wind direction correction. A local wind direction correction from AMSR-E in

the Australia vicinity was then compared with wind analyses by the Japanese Meteorological Agency (JMA). Global images were shown of the AMSR-E SST descending December 1, 2002, data and the AMSR-E SST ascending December 1 data, followed by monthly AMSR-E SST December 2002 data, for daytime, nighttime, and day/night combined data. Shibata indicated overall SST retrieval accuracies of 0.649 K for July-September 2002, 0.702 K for October - December 2002, and 0.741 K for January - March 2003, noting that the degradation in accuracy over time is not fully understood.

U.S. AMSR-E SSTs

Minnett took center stage again, this time to present the SST status and results for the U.S. AMSR-E Science Team, stepping in for Frank Wentz and Chelle Gentemann, who were unable to attend. Wentz and Gentemann have devised a correction for the uncertainties in the measurements of the temperature of the AMSR-E hot load and have based the SST algorithm for AMSR-E on the SST algorithm for the Special Sensor Microwave Imager (SSM/I). The AMSR-E ocean data products are produced on a near-real-time basis, and daily, three-daily, weekly, and monthly averages are all available to team members via FTP, for wind speed, SST, and other variables. Normally, on-orbit calibration for microwave instruments is performed by interpolating between a hot load and a deep-space (2.7 K) temperature. Because of uncertainties with the AMSR-E hot load temperatures, this procedure is inverted to calculate the hot load values. Radiative transfer modeling is used, driven by geophysical fields derived from the measurements of microwave radiometers on other satellites and using the Optimally-Interpolated (OI) SSTs of Reynolds poleward of the 40° limit of the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) SSTs. Roy Spencer further explained Frank Wentz's use of the SSMI and TMI measurements for tuning the AMSR-E products.

Coefficients for the AMSR-E SST calculations change daily, creating a concern raised by Joel Susskind regarding the use of the SST product in climate studies. Spencer clarified that the calibration changes continuously because of changes in the sun angle. The root-mean-square (RMS) difference between AMSR-E and Reynolds SSTs is 0.71 K. Minnett explained that the AMSR-E measures sub-skin temperature, through approximately the top 1 cm of the ocean surface. He showed AMSR-E versus MODIS SST comparisons and indicated that the AMSR-E SSTs have shed light on the MODIS SST quality, establishing that the MODIS cloud screening needs to be revisited. Differences between the MODIS and AMSR-E are apparent, and Minnett concluded that we do not yet know enough to establish which SST product is better. Furthermore, there is a digitizer issue with AVHRRs, creating a likely possible error in the Reynolds OI fields, in particular in the high southern latitudes. This issue with AVHRR has been recognized just within the past year, partly as a result of comparisons with MODIS data. Much discussion then ensued, involving AMSR-E, MODIS, and AIRS science team members, plus NASA Headquarters.

AIRS SSTs

The session then turned to the SSTs derived from the AIRS instrument. **Chahine** introduced this segment by mentioning that the AIRS team has selected almost a perfect window channel to derive the SSTs. He then turned to George Aumann to give the presentation on "AIRS Sea Surface Observations."

Aumann explained that the AIRS SST is derived from the 2616-wavenumber (3.8-μm) channel, restricted to nighttime cloud-free ocean conditions. The SST is inferred from first principles using an atmospheric transmission and surface emissivity correction. Although the atmospheric absorption in the 2616-wavenumber channel is less than 0.5 K even under particularly bad conditions, measurement accuracy at the 0.1 K level for climate studies mandates a careful correction for atmospheric transmission. Aumann listed three methodologies for atmospheric corrections. The best method uses temperature and moisture profiles inferred from the AIRS data, and results derived from this method will be available soon. Until then, the atmospheric correction can be made to within 0.1 K either through a method of Larrabee Strow using temperature and humidity profiles from ECMWF or through a method of George Aumann using the depth of weak water lines in the AIRS spectrum. In all cases, the Masuda model ocean emissivity correction is used.

The global map of AIRS-derived SST for December 2002 shows the expected large-scale global patterns. However, when the SST field is compared with the Real-Time-Global SST (RTG SST) produced by NCEP using buoy data, ship observations, and SST retrievals from spacecraft, interpolated with a global circulation model (GCM) on a 0.5-degree global grid, two intriguing effects emerge. First, AIRS SSTs agree with the RTG SSTs with a standard deviation of 0.44 K and a global bias of

only 0.65 K. Second, in areas as large as Australia, AIRS measures skin temperatures up to 2 K colder than the RTG SST. Aumann explained that a global bias of 0.65 K would be an excellent agreement for a measurement based on first principles, but that the agreement is, in fact, even better. Since the RTG SST represents the day/night average of the bulk (buoy) temperature, not the skin temperature measured by AIRS, 0.3 K of the measured 0.65 K bias was expected on that basis. The remaining 0.35 K bias was not expected and has the characteristic of an absorbing layer in the atmosphere, possibly aerosols. With the growing attention to aerosol absorption over the oceans in climate research, the ability to characterize this absorber spatially and spectrally at night through use of the AIRS data opens a new research avenue. Aumann explained that although the spectral signature of cirrus clouds is virtually omnipresent in the "cloud-free" data, the effect of cirrus clouds on the SST derived from the 2616-wavenumber channel (SST 2616) is minimal. A second unexpected effect relates to the large areas where the AIRS SST is up to 2 K colder than the RTG SST. It is possible that both the AIRS 2616 (skin) SST and the RTG (bulk) SST are correct but that the skin temperature is simply much colder than expected.

Joel Susskind, also a member of the AIRS Science Team, made an important clarification: The SST measurements discussed by Aumann are not the standard AIRS SST product. The measurements discussed were based on one channel of AIRS data, were initially intended for the diagnostic of the AIRS radiometric calibration, and were optimized for cloud-free conditions. The AIRS standard SST product, in contrast, is derived using many of the 2378 AIRS infrared channels and will be available under clear and cloudy conditions.

Data Assimilation

Chahine then indicated the importance of hearing from the user community and asked **Bob Atlas** to provide a perspective from the Goddard Data Assimilation Office (DAO). Atlas listed three applications for the SST products: boundary forcing for numerical weather prediction; initial conditions and verification data for coupled atmosphere ocean GCM simulations; and calculation of air-sea fluxes. Atlas explained that data assimilation systems are changing rapidly and that the current DAO model has 100-km horizontal resolution. The expectation is that within 10 years the resolution will be improved to less than 10 km. Requirements for the desired SST measurements include 50-km spatial resolutions now, 1-km spatial resolutions in 5-10 years, and accuracies of 0.1 K. Furthermore, for the purposes of data assimilation, Atlas would prefer to have the skin temperature rather than bulk or other ocean temperatures. He explained that errors in the SST fields can have significant impacts on the simulated atmosphere in fewer than 10 days and that modelers would like to update SST once a day.

SST Mini-Workshop Conclusions

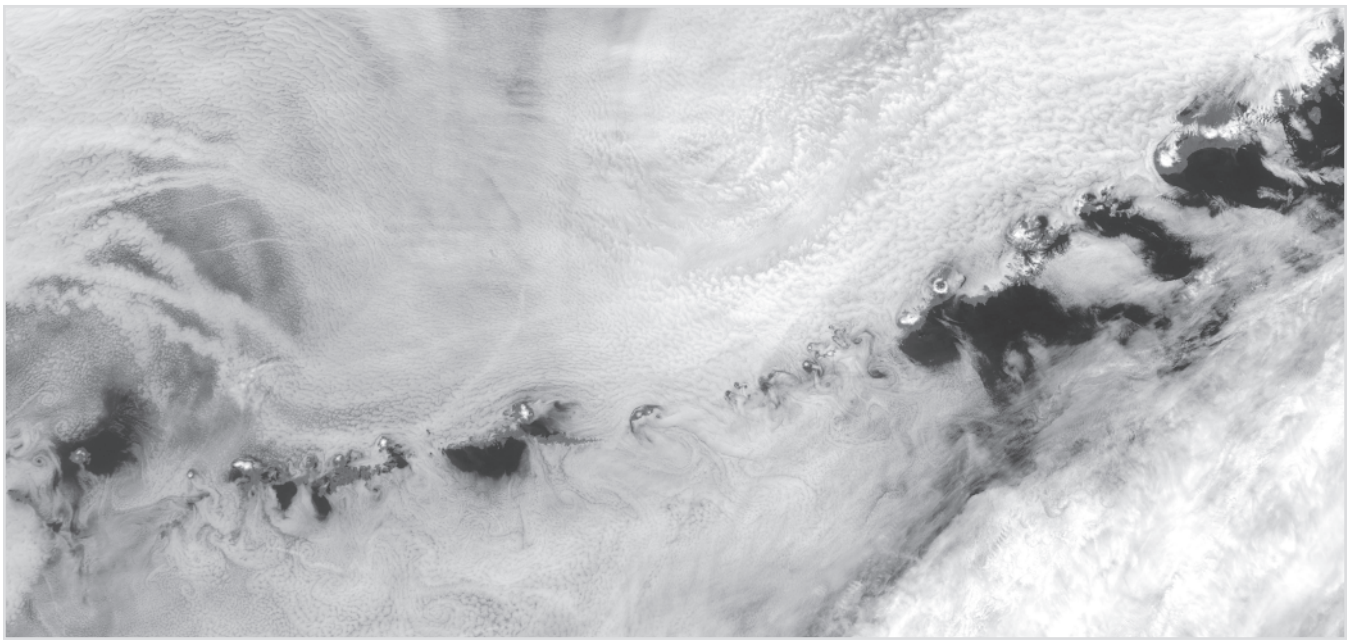
Chahine concluded that the Aqua science teams are doing extremely well, obtaining consistent SST measurements from the MODIS, AIRS, and AMSR-E. At this point, one year after launch, we have achieved within 0.5 K matching, which is much better than would have been expected two years ago. Jim Dodge from NASA Headquarters asked whether we want a combined product or will accept three separate SSTs from Aqua. Merging SSTs measured by different spacecraft radiometers ranks high in the objectives of the Global Ocean Data Assimilation Experiment (GODAE) High-Resolution SST Pilot Project, and many scientists agree that a merging of the Aqua SST measurements to a combined product could be valuable.

In closing Chahine asked: "Where do we go from here?" The participants indicated that there is a need in both hemispheres to cover regions poleward of 50°, where very few buoy data are available for the regression approach and an extremely small fraction of observations are indicated as cloud-free. This is not a simple problem and will require considerable work. On this note, Chahine concluded the SST workshop.

Mini-Workshop on Cloud Detection: Approaches, Needs, and Intercomparisons

The Thursday morning session (May 29, 2003), on "Cloud Detection: Approaches, Needs, and Intercomparisons," was chaired by the Deputy Aqua Project Scientist, **Steve Platnick**. Cloud detection and subsequent masking, needed for both clear and cloudy sky algorithms, is a common requirement for AIRS/AMSU/HSB, CERES, and MODIS algorithms. Seven speakers, representing each of these instrument teams, participated in the session.

Each retrieval algorithm has a unique set of requirements for cloud detection, ultimately driven by the spectral regions being used and the geophysical parameters being retrieved. Therefore, no single detection/masking approach can be expected to meet all needs. For example, some algorithms require



A fantastic array of clouds fills this Moderate Resolution Imaging Spectroradiometer (MODIS) image of the Aleutian Islands on July 3, 2003. The islands trail off the southern end of the Alaska Peninsula, separating the Bering Sea to the north and the northern Pacific Ocean to the south. In the image, the dissolving swirls of ship tracks are visible at left center edge, while surrounding the islands, the clouds are spun into eddies and vortices.

either absolute clear or cloudy scenes (e.g., most MODIS/CERES pixel-level retrievals), while other algorithms can work with a combination of the two in a footprint (e.g., AIRS/AMSU/HSB profile retrievals and the AIRS and MODIS CO_2-slicing cloud top property algorithm). The session was intended to help foster an appreciation for these various needs and provide an impetus for collaborative work.

As summarized by Platnick, the session addressed two broad items: (1) an overview and status of current cloud detection approaches and (2) presentation of detection and/or instrument intercomparison studies performed to date. In particular, this was the first science meeting bringing together the MODIS/CERES and AIRS/AMSU/HSB teams on these topics. Even within the MODIS science discipline teams (atmospheres, land, and ocean teams) and CERES pixel-level retrieval group, cloud masking approaches have evolved significantly since a Terra cloud mask meeting was held at the University of Wisconsin in May 2001; an update and extension to the full Aqua complement were deemed overdue.

AIRS Cloud Clearing

The first two talks were from the AIRS team. **Joel Susskind** began with a general overview of cloud clearing methods used by polar orbiting sounders, including the NOAA Television and Infrared Observational Satellite (TIROS) Operational Vertical Sounder (TOVS) based on the High-Resolution Infrared Radiation Sounder (HIRS) and the Stratospheric Sounding Unit/Microwave Sounding Unit (SSU/MSU) or AMSU instrument suite. In the sounder context, "cloud clearing" is synonymous with understanding how clouds impact scene radiances and not necessarily the elimination of cloud-contaminated sensor fields of view (FOVs).

There are three basic approaches to cloud clearing. The most restrictive is to use only cloud free FOVs (~13-km resolution for AIRS, ~20-km for HIRS), which severely limits retrieval coverage. In addition, there might be small amounts of cloud contamination in some fields of view judged to be clear. At the other extreme is to attempt a simultaneous solution for all cloud, surface, and clear sky parameters affecting the measured radiances, which requires knowledge of the spectral optical cloud properties. The intermediate approach, used to analyze both TOVS and AIRS, is to use adjacent sounder FOVs to reconstruct the clear sky radiances that would have been observed if the FOVs were completely clear. This is done with the help of microwave radiometer observations where multiple sounder FOVs are collocated with larger MSU or AMSU microwave radiometer footprints (two FOVs for TOVS HIRS, nine FOVS for AIRS). The method does not require optical cloud models. The algorithm utilizes a geophysical state, consistent with both collocated microwave

observations and observed IR radiances, to reconstruct the cloud cleared IR radiances used to retrieve atmospheric profiles and surface properties valid for the field of regard (FOR, the region covered by the multiple sounder FOVs). Quality control, based on how well solutions can be found that simultaneously match the cloud cleared IR radiances and observed microwave radiances, is used to accept or reject retrievals. Cloud products are subsequently produced. Atmospheric profile and surface parameter retrievals are produced in up to 80% cloud cover.

AIRS/AMSU/HSB products include all TOVS products (temperature/moisture profiles, surface temperature, cloud top pressure and effective cloud fraction, and outgoing longwave radiation and derived clear-sky outgoing longwave radiation) but with higher accuracy. In addition, ozone profiles, surface spectral emissivity, CO and CH_4 profiles, and CO_2 column retrievals are produced.

Susskind presented several AIRS/AMSU/HSB products as well as comparison studies. He showed RMS temperature differences between retrievals and ECMWF at different pressure heights versus cloud fraction. In general, the increase in error with cloud fraction is relatively small. At small cloud fraction, absolute RMS error is generally less than 1 K. The radiosonde, ECMWF, and retrieved profiles shown by Susskind for both temperature and water vapor revealed the retrievals and ECMWF water vapor results to be biased high compared to radiosondes (about 20% larger layer amounts near the surface, increasing to 50% at 350 mb). ECMWF personnel have shown that assimilation of AIRS clear-sky FOVs can add information to the model forecasts.

In conclusion, Susskind mentioned that the AIRS/AMSU algorithms are still evolving and that further algorithm improvements are expected to be delivered in the next six months.

Susskind was followed by **Chris Barnet**, also from the AIRS Team, who gave a comprehensive tutorial of the AIRS/AMSU/HSB cloud-clearing algorithm. Cloud clearing removes effects that are proportional to cloud fraction. It does not require cloud optical models. Barnet noted that Aqua provides an opportunity to merge sounder and imager concepts, from AIRS/AMSU and MODIS, respectively.

For an initial example, Barnet presented a two-FOV, single-cloud-type retrieval of cloud clearing and discussed measurement noise issues and spectral correlation of errors. Regarding this issue, the cloud-clearing algorithm has the advantage that error estimates are well-known. Complications arise when cloud optical properties are a strong function of wavenumber, while multiple cloud formations yield a non-unique solution. The use of nine AIRS FOVs allows for the determination of multiple cloud types. Barnet noted that calculations of cloud-cleared IR radiances from higher spatial resolution imagery (e.g., AIRS visible channels and/or MODIS channels) is difficult because of a lack of knowledge of cloud emissivity as well as angular and spatial sampling issues.

Barnet showed a global example of effective cloud fraction. Though clouds are currently underestimated, there are rarely (<2%) AIRS FORs that have cloud fraction less than 2%. Total precipitable water comparisons between AIRS retrievals and ECMWF were also shown to demonstrate that the quality of the retrieval is not a strong function of cloudiness. To illustrate this point further, Barnet compared the AIRS cloud cleared spectral radiances over the Pacific Ocean with forward calculations from ECMWF analysis for a scene with 30% cloud fraction. The differences were similar to those seen in radiances from locations believed to be truly clear.

Barnet then turned to the motivation for algorithm enhancements and upgrades. While the current cloud clearing approach is sufficient for meeting temperature and moisture goals, research products (CO, CO_2, CH_4) may require improved cloud clearing. Improvements would come, for example, from better land emissivity information and the detection/correction of uniform thin cirrus. AMSU retrievals and radiances are used as ancillary information within the AIRS profile retrievals; however microwave instruments require complex antenna side lobe corrections. Alternate approaches to the use of AMSU data should be examined for risk reduction, including the use of MODIS clear-radiance products (e.g., as an estimate for AIRS clear-sky radiances either through MODIS-AIRS radiance regressions or a combination of AMSU and MODIS data). Such an investigation might also have the added benefit of leading to other MODIS-AIRS research products.

MODIS Operational Cloud Mask (MOD35)

Rich Frey from the MODIS Science Team described the development history and status of the operational MODIS cloud mask (standard data product MOD35) and gave an overview of recent MODIS/AIRS cloud detection comparisons. He began by discussing the practical considerations involved in producing an operational

day-and-night 1-km global data set, including processing time, size of the data output, and comprehension/usefulness to the user, all of which impose certain design constraints on the algorithm. MOD35 also includes a 250-m daytime mask derived from the 0.65 and 0.86-µm bands and uses the 1-km mask results as ancillary information.

The 1-km mask uses threshold techniques applied to as many as 20 spectral bands and a variety of "surface domain" tests. There are two thresholds for each test, allowing for assignment of a confidence level. The mask uses no other MODIS products and little ancillary data. Clear-sky "restoral tests" are used to check for unambiguous clear-sky signals. The overall confidence levels derived from all individual test results are written to bits 1 and 2 of the mask (which consists of 48 bits of output per pixel). The mask is clear-sky conservative in the sense that it assesses the likelihood of a pixel being clear and that the overall confidence of being clear is zero if any single test has a confident not-clear outcome. The philosophy was to try to satisfy the basic cloud detection needs for as many MODIS algorithms as possible.

Validation approaches involve image analysis, field data, consistency checks, global statistical analysis, and comparisons with other satellites (e.g., in the NOAA Polar-Orbiting Environmental Satellite (POES) program). Example results from these validation categories were shown, including results over the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site in Oklahoma and direct broadcast acquisitions from the University of Wisconsin.

Comparisons with AIRS FOVs have been investigated by Dave Tobin and Steve Ackerman at the University of Wisconsin. An AIRS FOV clear sky confidence was defined as the number of confident clear MODIS pixels divided by the number of MODIS pixels in the FOV. Several examples were discussed, including the probability of finding confident clear sky as a function of FOV size and AMSU FOR. As expected, the probability drops substantially relative to the reference 1-km MODIS FOV.

Frey next showed global clear-sky confidence maps overlaid onto various MODIS bands (bands 2, 22, 26, 27, and 31). Of particular interest was the sensitivity to thin cirrus detected with band 26 (1.38-µm). Band 26 can detect much more thin cirrus than is reported in the basic cloud mask (bits 1 and 2). While the frequency of thin cirrus is of general interest for a number of scientific reasons, at some low optical thickness, it will cease to impact significantly infrared window channel measurements. Further study is needed within the MODIS community to quantify the thresholds of thin cirrus "cloud contamination" for each clear-sky product. In summary, Frey concluded that we still need to learn how to make good use of the information contained in the 1.38-µm band.

Imager Cloud Masking in Support of CERES

Pat Minnis from the CERES Team gave an overview of cloud masking using MODIS that is being done in support of CERES products, along with initial intercomparisons. For the CERES efforts, the mask and subsequent MODIS retrievals are collocated and averaged over a CERES footprint (10-50-km). Imager retrievals (as distinguished from CERES products) done by the CERES group at Langley Research Center (LaRC) include a comprehensive set of cloud properties, aerosol optical depth over the ocean, and clear-sky properties such as spectral surface emissivity and albedo. Unlike the approach used in the MODIS operational cloud product (MOD06), the CERES philosophy is to perform imager retrievals on every possible pixel in an attempt to maximize cloud information for use with ADMs.

The cloud mask approach described by Minnis includes multispectral thresholding based on clear scene characterizations along with spatial coherence tests in the visible to eliminate sub-pixel clouds over the ocean. The result is several classifications for clear and cloudy skies. Cloud signatures are designated as strong, weak, and glint; clear as strong, weak, snow/ice, aerosol, smoke, glint, and fire. Retrieval results are used as feedback. The fuzzy logic mask of Ron Welch from the University of Alabama at Huntsville is used to refine results. Prior to Terra and Aqua, the mask was applied to the TRMM Visible Infrared Scanner (VIRS) imager (2-km resolution).

The mask uses MODIS spectral bands at 0.65, 1.6, 3.7, 11, and 12-µm. Ancillary information includes ECMWF analysis (profiles every 6 hours, 3-hour skin temperatures), surface elevation, surface water and ice/snow information, and International Geosphere-Biosphere Programme ecosystem type. The mask results are available averaged onto a 1° grid as well as the CERES footprint.

Thresholds and their uncertainties are derived from model estimates of clear-

sky radiances (solar and IR). The solar model uses empirically derived clear-sky visible band albedo for overhead-sun illumination and ecosystem-based bidirectional reflectance models. In the IR, spectral surface emissivity is also empirically derived. An example granule-level comparison of observed clear-sky MODIS reflectance and IR emission and model results showed good agreement. Mask validation is similar to the MOD35 team approach (image analysis, climatologies, surface observations). Minnis showed comparisons with surface observations, VIRS retrievals, and data from the International Satellite Cloud Climatology Project (ISCCP). Though there are seasonal and latitudinal variations among the comparisons, ISCCP cloud fraction is typically larger than the MODIS-derived values, perhaps due to its use of lower spatial resolution imagery.

Minnis showed comparisons between the LaRC MODIS cloud mask and the operational MODIS mask (MOD35) for a number of example granules. The LaRC mask category "good" and the MOD35 "confident cloudy" designation were generally in good agreement. Problem areas include sun glint, desert, and snow/ice surfaces. Twilight regions are also problematic.

Minnis concluded by summarizing future mask activities and current data availability. Terra MODIS (Edition 1a) is available for the following time periods: March-August 2000, November-December 2000, and January 2001 - March 2002; Aqua MODIS (Beta 1) is available for September-November 2002 and January 2003.

Cloud Masking Approaches for MODIS Geophysical Products

The next three talks discussed cloud masking approaches being used by individual MODIS discipline groups in producing operational products. These internally generated cloud masks are not output as separate products. **Peter Minnett** from the MODIS ocean discipline group and the University of Miami led this set of three talks by presenting the operational cloud detection algorithm used by the ocean group. He highlighted the importance of the cloud masking by explaining that unacceptable errors in the ocean color and SST retrievals occur with just 1% fractional cloud cover, requiring an extremely conservative cloud detection algorithm.

Minnett first discussed the daytime algorithm, which involves a relatively simple two-part process. In band 14 (678 nm), the ocean is nearly uniformly dark and the largest variations in very turbid, coastal waters are comparable to the smallest cloud signatures. Therefore, spatial coherence tests can be an effective means of cloud discrimination. Such a test is applied to a 3x3 block of pixels after Rayleigh, ozone, and sun glint corrections. The glint correction uses a simple wind-speed dependent algorithm. For processing efficiency, the spatial tests are applied before aerosol corrections. To date, an additional reflectance threshold test is not used since it did not detect additional clouds beyond those found with the spatial test. Regions with max-min reflectance differences of less than or equal to 0.01 are considered free of cloud contamination. Then SST retrievals are compared with Reynolds Optimum Interpolation (OI) SST fields; if the discrepancy is greater that 6 K, the pixel is flagged as cloud contaminated.

For nighttime SST retrievals, spatial homogeneity tests are applied to 3x3 pixel arrays of the differences of SSTs calculated from 4-µm data and the SSTs calculated from 11-µm data. An additional test involving brightness temperature differences between bands 22 (3.9-µm) and 23 (4.0-µm) is applied; differences greater than a scan angle dependent threshold are flagged as cloud contaminated. As a final step, SST retrievals are compared with Reynolds OI SSTs using the same 6 K discrepancy threshold as for the daytime SST algorithm.

Minnett then discussed global statistics on AMSR-E SST and MODIS 11-µm SST retrieval differences. Though the greatest frequency of collocations is at a 0 K difference, there is significant spread (approximately ±2 K), and joint probability distributions indicate a secondary difference mode at about 5 K. This probably indicates some residual cloud-contamination in the MODIS retrievals. In summary, Minnett stated that the MODIS ocean cloud detection algorithm misses some low, uniform cloud decks and probably thin cirrus. The use of a 6 K threshold in the Reynolds OI SST comparison (compared with 2 K for AVHRR Pathfinder studies) has allowed some leakage of cloud-contaminated pixels. However, some level of residual cloud-contamination has to be tolerated, since to exclude all cloud effects would mean rejection of significant ocean signals.

Following Minnett, **Nazmi Saleous** gave an overview of the various cloud mask approaches used by the MODIS land team. With one exception (the fire product), either the operational mask (MOD35) and/or a mask based on the land surface reflectance product (MOD09), referred to as the "MOD09 internal mask", are/is used. The surface reflectance product uses the MOD09 internal mask exclusively. The snow product uses the overall cloud

confidence result from MOD35 (i.e., the first two bits of the mask) as well as individual MOD35 spectral tests. Surface temperature products use only the MOD35 overall confidence result. The vegetation index, bidirectional reflectance distribution function (BRDF), albedo, leaf area index (LAI), and fraction of photosynthetically active radiation (FPAR) use the MOD35 overall confidence result and the MOD09 internal mask. The fire product uses its own internal mask.

The MOD09 internal mask uses a mid-infrared anomaly test for low clouds, based on the difference between band 20 (3.7-µm) reflectance and a linear combination of bands 6 (1.6 µm) and 7 (2.1 µm). High clouds are detected with a band 26 (1.38-µm) test. A thermal test based on the difference between the MODIS brightness temperature and NCEP near-surface air temperature is used to assist over bright surfaces. Saleous showed several granule-level examples demonstrating the utility of each test. He also showed comparisons with the MOD35 cloud mask and an example of the land group's shadow mask. The mask is based on geometric calculations derived from cloud top height (estimated from cloud and surface temperature).

In summary, Saleous stated that further evaluation and improvements are needed for both the MOD09 internal cloud mask (e.g., over water bodies) and the shadow mask. The land group would like to collaborate with the MOD35 cloud mask group as these studies evolve.

Finally, **J. Vanderlei Martins** discussed an operational spatial variability technique being used to supplement cloud masking for MODIS aerosol retrievals (MOD04) over the ocean. Masking for aerosols is unique from other clear-sky products in that heavy aerosol plumes are often eliminated from clear-sky conservative masks. The spatial variability test in the latest delivery is applied to 3x3 arrays of 500-m band 4 (0.55-µm) pixels at each 500-m pixel (instead of the previous version where variability in 3x3 500-m pixel arrays were analyzed every 1.5 km). The new version improves the detection of cloud edges with acceptable increases in processing time. Next, only pixels within the 25-75% percentile in 10x10-km arrays are used for retrievals. This acts to further eliminate cloud contamination without biasing results. Finally, several individual spectral tests from the MOD35 cloud mask are applied to detect thin cirrus and homogeneous cloud fields — the 6.7-µm high cloud water vapor test (bit 15), window IR thin cirrus test (bit 11), and the IR temperature difference test (bit 18). These tests allow for aerosol optical depths up to about 5.0. Details can be found in Martins *et al*. (*GRL*, 2002).

Other improvements in the latest delivery include cloud discrimination over sunglint, the use of a 1.38-µm thin cirrus test (Gao *et al.*, *GRL*, 2002), use of a new coastal sediment mask (Li *et al.*, *TGRS*, 2003), a high visible reflectance threshold test, and thresholds of 0.47/0.67-µm used to detect high optical depth dust scenes having large variability and thick dust scenes over sunglint.

Martins showed examples of the standard deviation for both 3x3 500-m and 1-km resolution, along with histograms over ocean and land scenes demonstrating selection of standard deviation thresholds. He also showed examples over dust and sun glint.

Current work is proceeding on applying a similar approach over land. This includes higher variance thresholds, a large band 0.47-µm reflectance threshold to detect thick homogeneous clouds, spatial variance and absolute reflectance thresholds at 1.38 µm, and ratios of 1.38-µm to 0.66-µm for cirrus detection. Results to date are very promising.

Platnick and Parkinson then thanked the speakers and attendees for their participation in this first, highly successful attempt to compare products from across the Aqua platform in a workshop setting. The SST mini-workshop on May 28 and the cloud detection mini-workshop on May 29 both brought together members of all the Aqua science teams to cross-compare products and consider the enhanced understanding of the Earth system possible through the combined use of the six instruments on the Aqua platform.

Report on the Physical Oceanography Distributed Archive Center (PO.DAAC) User Working Group Meeting - April 22-23, 2003

— Jorge Vazquez, jorge.vazquez@jpl.nasa.gov, Jet Propulsion Laboratory

The regular meeting of the Physical Oceanography Distributed Active Archive Center (PO.DAAC) User Working Group (UWG) was held April 22-23, 2003, at the Raytheon/ITSS facility in Pasadena, CA. Those in attendance included UWG members R. Evans (chair), David Glover, John Lillibridge, Sydney Levitus, W. Timothy Liu, C.-K. Shum, and Victor Zlotnicki (ex-officio), with the manager of the PO.DAAC, Donald Collins, chairing the meeting.

The meeting began with an overview of the future direction of the PO.DAAC. The overview will be incorporated into the preparation of a strategic plan of the PO.DAAC. This strategic plan will include how the PO.DAAC will function in a competitive environment and maintain a cost-effective mechanism for data distribution. A review of the goals of the PO.DAAC was discussed.

Goals

The primary goal was for the PO.DAAC to be the lead center for distribution of satellite-derived sea-surface topography and ocean vector-wind products. Additionally, the PO.DAAC will become the lead center for air-sea interaction data sets. Air-sea interaction data sets will include SST as well as other derivable products such as surface fluxes. The goals were discussed in terms of integration into NASA's Earth Science program.

A NASA focus is now on the production of long-term climate data records (CDRs) and providing the data streams to support the modeling community. Such CDRs will include both long-term time series and data from multiple missions. A challenge for the PO.DAAC will be providing the satellite-derived oceanographic component of these CDRs. As more missions and data sets related to CDRs come on line, the PO.DAAC will maintain its level of user support and data distribution. Part of the challenge is distributing these data sets in an operational near-real-time mode. To measure success, new and improved metrics are needed that record all publications which include CDRs. The discussion included possible scenarios for automating the process of keeping records on data publication and usage.

Missions

Discussions also arose on the role of the PO.DAAC in future missions such as the Ocean Vector Wind Mission (OVWM), the Ocean Surface Topography Mission (OSTM) on the Japanese Global Change Observation Mission (GCOM), and the Aquarius Mission. Such missions will include the co-operation of the PO.DAAC with other agencies such as NOAA. One of the unique aspects about the PO.DAAC is its direct linkage to the flight projects. This allows for the PO.DAAC to provide a level of expertise in the data sets from the beginning of the mission, including the system engineering, data formats, data content, and the long-term data stewardship. Such experience has been gained over several flight missions including TOPEX/Poseidon, NSCAT, QuikScat, and Jason-1. Such experience will be carried forward into future flight projects and missions.

Conclusions

Increasing emphasis will be placed on the electronic distribution of data. This includes looking at new technologies involving data transfer that improve on the file transfer protocol (ftp). Additionally, the incorporation of better subsetting for Level 2 and Level 3 data products remains a high priority.

The meeting ended in agreement that the PO.DAAC is providing an excellent service to its customers, both technically and scientifically. Additionally, it supports the educational community through data products, brochures, and community outreach. The members in attendance agreed that the primary challenge would be for the PO.DAAC to maintain its level of service, while increasing the number of data sets and products it supports.

May 2003 User Working Group Meeting - ORNL DAAC for Biochemical Dynamics

— Robert Cook,cookrb@ornl.gov, Oak Ridge National Laboratory
— Larry Voorhees, voorheesld@ornl.gov, Oak Ridge National Laboratory
— Curtis Woodcock, curtis@crsa.bu.edu, Boston University

The User Working Group of the Oak Ridge National Laboratory (ORNL) DAAC met on May 21-22, 2003, in Oak Ridge, Tennessee. The meeting was attended by UWG members Indy Burke, Ken Davis, Ruth DeFries, Mac Post, Peter Thornton, Curtis Woodcock (UWG Chair), and Quinton Barker (ESDIS Representative). From the ORNL DAAC, Tim Rhyne (Systems Engineer), Larry Voorhees (DAAC Manager), and Bob Cook (DAAC Scientist) attended the meeting; DAAC staff participated in several parts of the agenda.

The ORNL DAAC supports the Earth Science Enterprise (ESE) and the Earth Observing System (EOS) by providing data and information about the dynamics between the biological, geological, and chemical components of the Earth's environment. Sources of data held by the DAAC include NASA-funded field campaigns, (such as BOREAS, LBA, and SAFARI 2000), selected relevant measurements from EOS satellites, as well as other biogeochemical dynamics data useful to the global change research community. The DAAC supports EOS validation by providing data from Land Validation field activities, as well as 7x7-km subsets of MODIS Land Products in ASCII format. The Web Site for the ORNL DAAC is *www.daac.ornl.gov*.

Following a review of the status of DAAC activities, the meeting focused on future plans.

DAAC Activities Status Report

- From July 2002 to April 2003, the ORNL DAAC archived 26 data sets from the following projects (SAFARI 2000, BOREAS Follow-On, Net Primary Productivity, FLUXNET, and Prototype Validation Experiment (PROVE)), as well as global vegetation and global root data sets.
- In support of validation activities, the DAAC provides subsets of key MODIS land products for 274 sites in ASCII format for comparison with field data. The following MODIS products are being offered: surface reflectance, surface temperature, land cover, enhanced vegetation index, leaf area index / fraction of photosynthetically active radiation, photosynthesis, albedo, and nadir BRDF-adjusted reflectance.
- The ORNL DAAC has developed a Web map server to help users locate field sites from around the world. The DAAC has Web map servers, based on the Minnesota MapServer for more than 210 sites in the FLUXNET global network, for more than 270 sites that have MODIS ASCII Subsets, and more than 60 sites from the Net Primary Production project. Users can select a group of sites and retrieve available site characteristics and data.
- For the FLUXNET collection of carbon dioxide flux measurements, the ORNL DAAC registered 216 towers from 11 networks world-wide and provides gap-filled flux data for 176 site-years from 53 sites.
- In support of biogeochemical dynamics modeling activities, the ORNL DAAC has provided a metadata registry for regional and global environmental data held at data centers around the world. Over 180 data sets on vegetation, climate, soils, gas exchange, and hydrology are registered in Mercury, the ORNL DAAC's metadata search and data retrieval system.
- During CY 2002, the ORNL DAAC delivered over 53,961 data products to 5,030 distinct users; the most popular data sets were FLUXNET, Net Primary Production, SAFARI 2000, Global Climate data, and River Discharge (RivDIS).
- Mercury-EOS, a client for ECHO, was deployed in April 2003. This system will allow users to search ORNL DAAC holdings and order via ECHO's centralized ordering mechanism. ECHO, the EOS Clearinghouse, is a system developed by ESDIS to query for data and place orders like commercial e-commerce entities.

- The DAAC has developed a Web-based tool for investigators to prepare documentation for *in situ* data sets. Currently, the tool is being evaluated by selected LBA participants.

Data Activities: The NA Carbon Program

The North American Carbon Program (NACP), one component of the U.S. Global Change Research Program, is a multi-agency research program to study sources and sinks of carbon in North America and adjacent oceans. Because of the close relationship between the goals of the NACP and the mission of the DAAC, the UWG discussed ways in which the DAAC should be one of many data centers involved in the NACP (e.g., NOAA-National Climatic Data Center (NCDC), Carbon Dioxide Information Analysis Center (CDIAC), LP-DAAC, and NOAA-Climate Monitoring and Diagnostics Laboratory (CMDL)).

The UWG recommended that the ORNL DAAC should be involved in the preparation of the implementation plan for NACP and involved in compiling and distributing *in situ* data during NACP.

Archiving Models

The UWG suggested at the July 2002 meeting that the ORNL DAAC could play an important role in archiving numerical models that represent terrestrial biogeochemistry, including land-atmosphere exchange of carbon. There are a number of reasons for archiving models: to enable others to reproduce the results of a published study, to provide an estimate of uncertainties for comparison with results from other models in assessment/policy studies, and to provide the source code, which allows others to see how models treat individual processes. The model archive at the ORNL DAAC is envisioned as a resource for experienced modelers, and is not intended for novices or as an instructional tool.

Within three months, the UWG and the ORNL DAAC will write a position paper for open literature to describe the importance of creating a model archive. As a complement to that paper, the DAAC will write a set of guidelines for preparing information for a model archive (documentation, source code, representative input and output data, and post-processing / analysis code). As part of the FY 2004 activities, the DAAC will begin to archive high-priority biogeochemical dynamics models.

During the discussion of archiving models, the UWG suggested that NASA should have a Model Policy to go along with the existing Data Policy. The UWG will pursue this after the position paper has been finalized.

Land Validation and Field Investigation Subcommittee

A summary of a recent Land Validation and Field Investigation Subcommittee meeting was presented. Six UWG members held a teleconference May 19, 2003.

The subcommittee discussed unauthorized use of project data. Several projects supported by the ORNL DAAC (SAFARI 2000, Land Validation, and FLUXNET data) have data policies that request users contact the investigator before using the data. There have been several instances of researchers publishing project data without contacting investigators for permission, or properly citing the source of the data. In response to these instances, projects have come up with a couple of possible solutions, including prominently posting the data policy at the top of each data file.

The DAAC also requested guidance from the subcommittee on how best to move data from the Land Validation version of Mercury into the archive. The subcommittee suggested that the DAAC focus on those data used to validate land products. If such validation data are in Mercury, the DAAC should contact investigators to ensure that data are ready for archiving. If data that have been used in validating land products are not in Mercury, the MODLAND Science Team should contact investigators to obtain data and metadata.

The subcommittee discussed the following data activities the DAAC can perform to support the Committee on Earth Observing Satellites (CEOS) / Working Group on Calibration and Validation (WGCV):

- Continue to attend WGCV topical meetings to provide DAAC experience and offer ways the DAAC can contribute (e.g., Albedo Workshop, October 2002);
- Continue to register data from international LAI intercomparison activities in Mercury;
- Prepare and post MODIS ASCII Subsets for International WGCV intercomparison sites; and
- Provide data management support: field data and metadata preparation, data set distribution, compilation of site characteristics data from literature, preparation and distribution of value-added products.

UWG photo, at the Walker Branch Watershed Flux Tower site. (From left to right: Peter Thornton, Tim Rhyne, Mac Post, Tilden Meyers, (NOAA, Walker Branch Watershed Flux Tower PI), Ken Davis, Quinton Barker, Indy Burke, Ruth DeFries, Bob Cook, and Curtis Woodcock). Photo Credit: Larry Voorhees.

Regional and Global Data Subcommittee

The UWG heard a report from the Regional and Global Data Subcommittee. Seven UWG members participated in the teleconference on May 8, 2003.

The DAAC summarized plans to archive regional and global data from recently completed projects. In the near-term the DAAC is planning to archive global allometry data, Siberian land cover, N-deposition data for the eastern U.S. and western Europe, global litter data, and the rangeland CO_2 flux data from the U.S.

Conclusion

With this meeting, Curtis Woodcock concluded his leadership role as Chair of the ORNL DAAC UWG for the period 1999-2003. The UWG and DAAC staff thanked Woodstock for his service. He was instrumental in implementing several important changes in the operation of the UWG. Early in Woodstock's term as Chair, he also ensured that the DAAC's activities and future plans were on target, so that the past several UWG meetings have confirmed that the DAAC is doing the "right thing" and no major issues have surfaced.

During the close-out session, the UWG members provided the following recommeµndations:

- The top priority should always be to increase the data holdings of the DAAC.
- Data quality, documentation and added-value of data holdings are all important considerations for the DAAC. The legacy of the DAAC is tied to the data in the archive.
- The model archive initiative is important, and DAAC staff should assist the UWG in writing a modeling position paper during the next three months.
- The North American Carbon Program (NACP) activity is central to the mission of the DAAC, and the DAAC should pay close attention to the NACP as it evolves.
- The UWG concluded the meeting by stating that the ORNL DAAC is currently fulfilling its mission to provide biogeochemical dynamics and terrestrial ecology data to the research community. The numbers of DAAC data users and numbers of data products downloaded each year continue to increase, and references to ORNL DAAC data in the peer reviewed literature are increasing.

Erratum

The Odyssey of the Mind World Finals were held at Iowa State University in Ames, Iowa, not University of Iowa as mentioned in our article titled "NASA's Earth Science Enterprise Sponsors Creative Problem Solving Competition" on page 30 of the May/June issue of *The Earth Observer*. Our apologies to Iowa State for this error.

Third Annual Earth Science Technology Conference a Success

— *Philip Larkin, plarkin@gst.com, Earth Science Technology Office*

The Earth Science Technology Office (ESTO) held the third annual Earth Science Technology Conference (ESTC), June 24-26, at the University of Maryland Inn and Conference Center. Designed to showcase leading-edge technology research funded by ESTO, the conference attracted over 300 technologists, scientists, researchers, and academics, as well as NASA managers and planners.

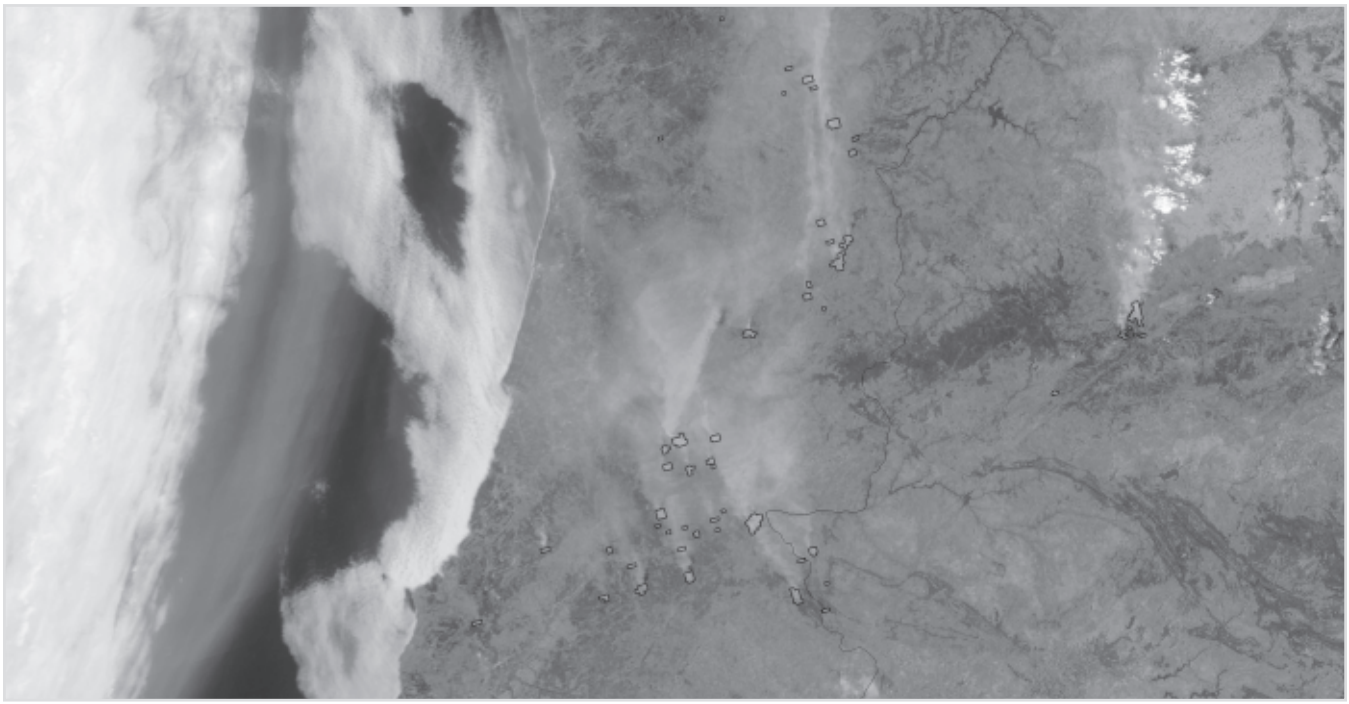
The conference agenda included 60 technical papers presented in two parallel tracks: Information Technologies and Observation Technologies. For the presenters, the three-day conference was an opportunity to report on their research and to communicate directly with NASA planners who may be able to incorporate their work into future science measurement missions. Plenary and Luncheon speakers included Fritz Hassler and Marshall Shepherd, NASA, and Doug Hill, Chief Meteorologist at WJLA-TV, ABC7.

For more information about the conference, or to download papers and presentations, go to the ESTO website at *esto.nasa.gov* and click on the ESTC link.

About ESTO

The Earth Science Technology Office develops new technologies for the NASA Earth Science Enterprise. Through diverse technology initiatives and careful planning, we provide the tools necessary to push the boundaries of knowledge and discovery and facilitate practical applications that benefit society at large.

For more information see the ESTO website at: *esto.nasa.gov*



On August 4, 2003, fires (rectangles) continued to burn across Portugal (left) and Spain (right), but the large cloud of smoke seen on the previous day had cleared. A severe European heatwave, with temperatures up to 40 degrees Celsius (104 degrees Fahrenheit), is contributing to the explosive growth of the fires. 11 people have died, and 54,000 hectares (135,000 acres) of woodland have been burned. This image was captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Aqua satellite during the afternoon of August 4, 2003. Image courtesy of Jacques Descloitres, MODIS Land Rapid Response Team at NASA GSFC.

The CERES S'COOL Project

— Lin Chambers , Langley Research Center, L.H.Chambers@larc.nasa.gov
— David Young, Langley Research Center, d.f.young@larc.nasa.gov
— P. Kay Costulis, Langley Research Center, p.k.costulis@larc.nasa.gov
— Pauline Detweiler, Langley Research Center, p.t.detweiler@larc.nasa.gov
— Joyce Fischer, Langley Research Center, j.d.fischer@larc.nasa.gov
— Roberto Sepulveda, Langley Research Center, r.sepulveda@larc.nasa.gov
— Douglas B. Stoddard, Langley Research Center, d.b.stoddard@larc.nasa.gov
— Amanda Falcone, Trinity University, San Antonio, Texas, Amanda.Falcone@trinity.edu

The lessons learned during the development and operation of a NASA outreach program can benefit other educational efforts linked to scientific projects.

Lesson One: Think Globally, Act Incrementally.

A short-term project is probably best done with a small, local audience. For a longer-term, extensive project, start slowly, incorporate teacher feedback, and allow time for your project to become known and appreciated.

The Students' Cloud Observations On-Line (S'COOL) Project was initiated in late 1996, before the launch of the three low Earth orbit satellites that now carry the Clouds and the Earth's Radiant Energy System (CERES) instruments. From the beginning, S'COOL was developed with input from teachers. Indeed, the idea for this project arose in a conversation between the first author and a sixth-grade science teacher. She was seeking a simple, safe, and cheap way to connect her students' in-class experiments to NASA. CERES, which was designed to monitor the Earth's radiation budget and how it is impacted by cloud properties (**Wielicki *et al.* 1996**), needed to validate cloud retrievals on a global basis. The teacher's class served as the first test site for S'COOL, confirming that students would be interested in the project. The scope of the S'COOL project was then expanded over the year leading up to the launch of the first CERES instrument [on the Tropical Rainfall Measuring Mission (TRMM) satellite on Thanksgiving Day, 1997, from Tanegashima, Japan]. **Table 1** summarizes the development phases of S'COOL. After each phase, teacher comments were solicited and used to improve the project. Specific lessons learned are included in **Table 1**. S'COOL was declared operational in April 1998. It now involves the part-time efforts of two scientists, two web and database specialists, and a fulltime former classroom teacher (part of the team since October 1997). A part-time teacher consultant was added in 2000 to focus on interaction with the Spanish-speaking audience. (Bilingual team members cover French and German translation needs.) In 2001, a part-time administrative assistant was added to keep up with the growing S'COOL community.

Lesson Two: Keep it Simple.

For teachers: Teachers have many demands on their time, so keeping outreach as simple and flexible as possible is imperative.

For students: What may seem trivial to scientists can be fascinating new knowledge to a young student.

To participate, interested teachers simply register. S'COOL needs a record of the location of each school in order to match their observations with the satellite. Each registered teacher receives a packet of information, including a colorful cloud identification poster. Upon registration, teachers are sent their first overpass schedule, telling them what time the satellite will pass over their school each day. Schedules are projected a maximum of two months into the future, since satellite orbit adjustments occur. Further schedules can be requested online at scool.larc.nasa.gov.

From the schedule, teachers select an overpass that fits their class situation. Students then go outside within 15 minutes of the satellite's passage to observe and record cloud and surface properties on a one-page report form. For an experienced class, this process takes only 5–10 minutes. Overpass schedules do not always mesh with school schedules, but solutions can be worked out. For example, a high school teacher reported the following: "Our overpass times are always while they are in classes other than science. We designed special S'COOL hall passes, and my colleagues who teach other disciplines have been very supportive and allow the students to leave class for five minutes to go outside and take their readings."

Table 1. The Development of S'COOL.

Dates	Test	Participants			Observations*	Lessons Learned
		No.	Location	Grade		
13-17 Jan 1997	Postal/ interface scientist visit	1	Peasley, MS Gloucester, VA	6th	Ground 5 Satellite 4	Importance of clear-sky observations. Need for a consistent cloud chart.
11-17 Mar 1997	E-mail interface/ remote site	1	Big Timber Grade school, Big Timber MT	6th	Ground 5 Satellite 0	Scientist visit is not necessary. Lots of multilayer clouds.
17-21 Mar 1997	Web interface	1	Poquoson Elementary Poquoson, VA	4th	Ground 5 Satellite 4	Potential of the Internet.
28 Apr-2 May 1997	National Test	9	AZ, GA, MT, NM NY, PA, SD, VA (2)	1-12	Ground 41 Satellite 17	System works for distributed sites and multiple grades.
Jul 1997	International test	0	No successful contacts in Southern Hemisphere		Ground 0 Satellite 0	Need time to make connections outside United States.
20-24 Oct 1997	Global test/ draft poster and brochure	26	AR (2), FL, IL, ME MI (3), NM, NY, SC, VA (3), France (7), Switzerland (4), Sweden	1-Univ. (Educ.)	Ground 119 Satellite 12	Need to be flexible for teacher schedules.
9-13 Feb 1998	TRMM satellite test	31	AK, CO, DE, FL, IL, MI (2), NY (3), OH, OR (2), PA, TX (3), VA (3), France (6), Norway, Sweden, Switzerland (3)	1-Univ. (Educ.)	Ground 168 Satellite 29	Teachers use S'COOL even outside test week (Nov-19 Feb 1998)

*Before TRMM launch, NOAA, AVHRR, GOES, and Meteostat data were used.

The observation is sent to NASA either by accessing an online form, or by sending an e-mail, a fax, or even a hard copy (a ground rule for S'COOL is that Internet access is not required, enabling us to reach students without computers). The S'COOL ground observations are stored in a database at the NASA Langley Atmospheric Sciences Data Center (ASDC); online at *eosweb.larc.nasa.gov*. ASDC is responsible for processing and archiving CERES data along with many other atmospheric datasets. During operational processing, CERES data corresponding to S'COOL observations are extracted and placed in the S'COOL satellite database. For the TRMM satellite, data are only available between about 35°N and 35°S latitude. In December 1999, the launch of two CERES instruments on the Terra spacecraft provided a daily morning overpass of the entire globe. The Aqua launch, with two more CERES instruments and a daily afternoon overpass, was on May 4, 2002.

Figure 1 shows the history of participants and ground and satellite observations in the S'COOL database. Within a month of sending their first observation (and for each new school year), a class receives a "S'COOL Observer" decal for each student. Teachers can also print certificates for each student from the Web site to recognize their progress, which can be substantial. For example, one teacher reported ". . . my first graders got very good at identifying the cloud types. I was impressed with their knowledge at such a young age."

Lesson Three: The Internet Advantage

The Internet is invaluable to facilitate communication with participants and to share information among them. There is also an increasing amount of useful information on the Web, which can be used for background and supplementary information.

The S'COOL ground and satellite databases are available via a public Web interface, for use by teachers in educational applications (such as graphing, mapping, and comparing). Lesson plans describing data-use projects are available. From this display, that data can also be downloaded into spreadsheets for analysis.

From the beginning, S'COOL observations have been a useful complement to the satellite information. The very first S'COOL observation occurred on a beautifully clear January day. Reports from cloud observers on clear days may seem dull but are very important. Determination of a completely clear sky from the satellite can be a challenge in certain circumstances, given the inhomogeneous background of the Earth's surface, but there is high confidence in the accuracy of students' report of clear sky. Other challenges to the satellite cloud retrieval algorithm include clouds over snow, subpixel-scale clouds, and very thin clouds—none of which pose problems for observers on the ground. When multiple cloud layers are present, the surface observation gives an additional data point from the bottom, while the satellite views the cloud top.

Instrument problems and data delays have slowed the production of satellite data, so that timely comparison of ground and satellite results has been a major challenge. Nonetheless, a statistical comparison using the limited

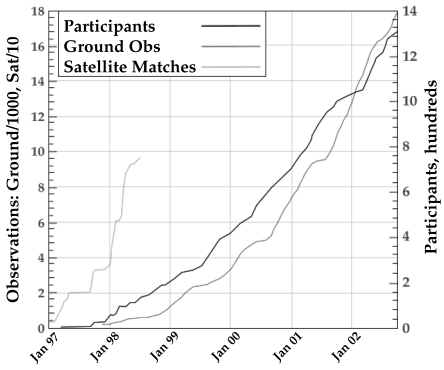


Figure 1 - Growth of S'COOL: The darkest line (middle) denotes the number of participants, in hundreds. The lightest curve (left) shows the number of matching satellite data, in tens. Only satellite data through 1998 have been processed so far. The last curve (right) shows the number of S'COOL ground observations, in thousands. Note the plateau each summer, associated with summer vacation in the Northern Hemisphere.

amount of satellite data now available is instructive. **Table 2** summarizes the cloud cover observed from the two vantage points, while **Table 3** summarizes the cloud layers observed. Note in the latter the nine cases where the satellite finds clear sky while ground observers report a single layer of cloud. In eight of these nine cases, surface observers reported 0%–5% translucent cirrus cloud cover, which was not detected by the satellite. Despite the delays with the satellite data, many participants have been very happy with the observational portion of S'COOL. Yet motivating all registered teachers to become active participants has been a challenge. Once routine processing of CERES data begins we hope to encourage additional teachers to become more active. S'COOL will, however, remain an elective project, used by teachers as time permits and interest dictates.

Lesson Four: Teachers Are Professionals, Too.

The ways teachers use a simple project to enhance learning will surprise you. CERES personnel (scientists and engineers) expected S'COOL to apply mainly to science and math education. In practice, teachers have used it for other lessons as well, and over an extremely broad grade level from kindergarten to graduate school. A teacher in phase 1 reported the following: "It was a perfect addition to our science weather unit and covered the standards of learning as well as spilling into other curriculum areas and getting the class out of the traditional classroom."

Observation skills. An elementary school teacher in Michigan uses S'COOL as an opportunity to foster observation skills in her students. Every day before class, they sit out in the courtyard and quietly observe their surroundings: seasonal and weather changes, animal life, vegetation, etc. As she says, "A significant part of science education is to help students sharpen their observation skills . . . S'COOL is highly motivating to the children." S'COOL provides students with a motivation to learn cloud identification, something that is required in most curricula. It also makes learning fun, as indicated in this comment: "The kids have been enjoying collecting their data. They feel very important since they are working with NASA."

Math skills. An elementary school teacher in Virginia reported that her students are so excited about S'COOL that they want to perform calculations of unit conversions themselves rather than relying on the Internet calculator page. Addition and division are reinforced while obtaining a class consensus for the value of fractional cloud cover and temperature.

Writing/descriptive skills. An elementary school teacher in Virginia has her students writing similes and descriptions of what they see while outside observing clouds (i.e., "the clouds look like moldy bread"). These are reported with their observations in the comments section of the report form and complement the more objective report of cloud type.

Foreign language skills. A school in Canada registered with S'COOL for the express purpose of using it to practice a second language. Several schools in Puerto Rico use S'COOL to practice English. An elementary school in Virginia used S'COOL as a focal point for supplementary language instruction offered by a bilingual parent.

Table 2. Cloud cover from satellite vs. ground observers.

Satellite \ Ground Observers	Clear	Partly	Mostly	Overcast
Clear	27	2	2	0
Partly	7	10	2	1
Mostly	5	3	12	7
Overcast	0	1	8	12

Table 3. Cloud layers from satellite vs. ground observers.

Satellite \ Ground Observers	Clear	Single	Multi
Clear	14	9	0
Single	3	29	3
Multi	3	29	9

Recently the Foreign Language Association of Virginia embraced S'COOL as a real-world application of language skills.

Technology skills. An elementary school teacher in South Carolina reported that this project was a good way to begin introducing the Internet and computer technologies to her students. In a number of elementary schools S'COOL becomes a multi-age project. For example, "I worked with a fourth grade class and that helped with the computer aspect. You might encourage other schools to combine a lower elementary room with an upper elementary room for increased participation and learning." Several college education professors use S'COOL to teach how to manage a class of students in a Web-based curriculum unit. Their motivation is expressed by this comment: "This project [is] a really nice connection to data collection/measurement and many other aspects of what I hope these 'becoming' teachers will do with kids when they get into the classroom.

Life skills. An elementary school teacher in France reported that he uses S'COOL to help teach his students about responsibility and being punctual. A high school teacher in Pennsylvania reports: "It's really a shot in the arm for us to have our kids eager to do anything. They go outside with instruments in hand, subtracting wet-bulb/dry-bulb readings to figure out humidity, and trying to read our ancient barometer, which has four scales on it. [. . . A learning disabled] science class is joining my . . . class when we go out. It's good for both sets of kids to see each other doing similar type of work. They take their "job" a little more seriously than most of my class; which serves as a motivational tool."

Scientific curiosity. While visiting a middle school in Paris, the first author watched students make relative humidity measurements following the simple directions on the S'COOL poster. The students were rather uninterested until they got to the last step and observed the change in temperature for the wet-bulb reading. This first-hand experience provided a teachable moment: why did this happen? During the snowy winter of 2000/01, a sixth-grade class in Illinois became curious about whether relative humidity affects the ability of snow to pack into snowballs. They began keeping records and tentatively concluded that it does.

Lesson Five: Two-Way Street.

Outreach efforts are more valuable if they incorporate teacher feedback. Scientists know science; teachers know teaching.

The CERES S'COOL project started from a conversation between a teacher and a researcher. The idea was developed with continuous feedback from teachers. As a result, the project has been very successful in the classroom and has provided learning and motivation to increasing numbers of students. S'COOL is available to all interested teachers for participation at their convenience, when it best fits their curriculum and schedule. The S'COOL materials and data are available for use by all.

S'COOL participants are part of the CERES validation team. We expect that they will pick up some interesting trends once matching satellite data become plentiful. Whenever possible,

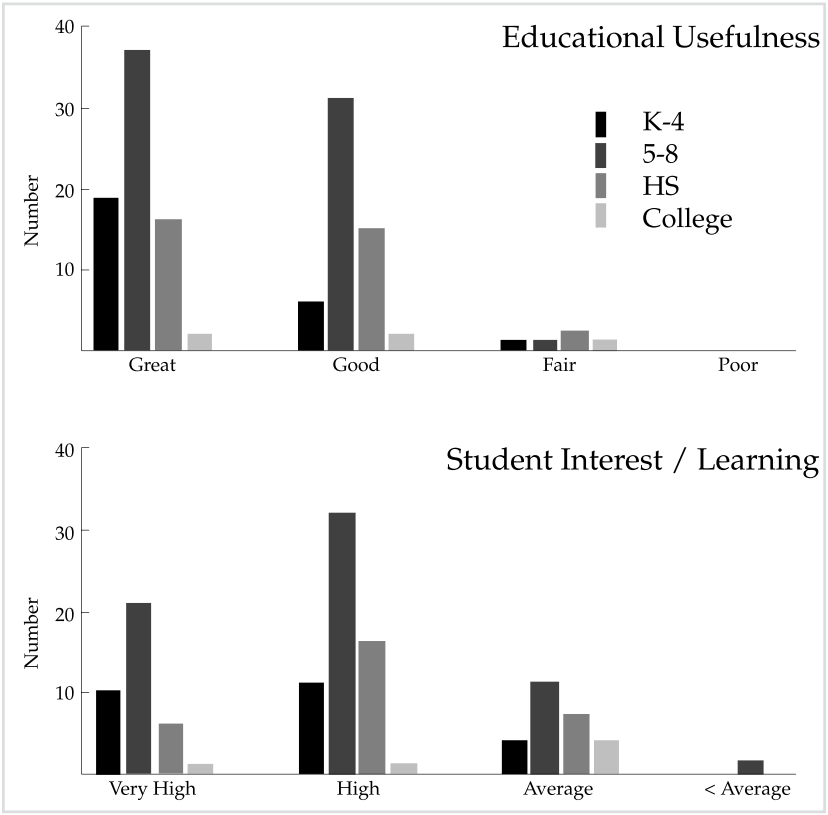


Figure 2 - Teacher rating of educational usefulness of and student interest / learning during the S'COOL Project, as recorded in a participant survey during Fall 2000.

CERES researchers and S'COOL personnel visit participating schools. A S'COOL "Wall of Fame" marks the location of each participating school. It is on display near CERES researchers' workplace, enabling them to make S'COOL visits a part of any trip they take. These visits are a very important element of S'COOL, allowing us to take the scientific message behind the project directly to the children, and to show them science's human face. As a Swiss elementary school teacher said, "Continue thus and persuade your colleagues to do the same. It is the truest way to 'germinate' vocations."

Since 1999 there has been a weeklong summer S'COOL workshop for teachers at NASA Langley Research Center. The week includes in-depth work with elements of the S'COOL Project, introduction to CERES science and scientists, and tours of interesting facilities around NASA. Said one participate, "I can never get enough of these guys explaining the science behind the experiments." This direct interaction between scientists and teachers, some of whom are experienced S'COOL teachers, never fails to result in ideas for new ways to help students learn. Lesson plans and other materials developed in these workshops are made available online for all participants.

A participant survey during Fall 2000 had a 20% response rate (134 respondents, which is about half of the then-active participants), and provided objective data as well as room for comments. A large majority of teachers rated the educational impact of S'COOL highly. Thirty-three teachers reported a total of 557 students showing increased interest in science as a career after being involved with S'COOL. The remainder of responding teachers said it was "too soon to tell." While this is a qualitative assessment, it is encouraging news for the S'COOL team.

Acknowledgments

Funding for S'COOL is provided by NASA's Earth Science Enterprise and Education Offices, and by CERES.

Our thanks, first, to Eleanor Jones, the sixth-grade teacher who inspired the idea for S'COOL; to Carol Mitchell, a local teacher who has been involved and helpful from the first phase; to Steve Campbell and others in NASA Langley's graphics section who developed and now continue the S'COOL "look"; to Carolyn Green, the first educational consultant for S'COOL, whose enthusiasm and hard work were key factors in the success of the project, and who, in her third career, is now a S'COOL teacher; to Anne M. Racel and Susan J. Haberer of the ASDC, the first and second Web "gurus" of the S'COOL Project, without whom we could not reach so many schools in so many places; to Ian McGlynn, Gretchen Blauvelt, and Allan Armenta, student interns; to Christine York, teacher intern, who contributed to the S'COOL Project; to all the teacher graduates of our summer workshops, and to all S'COOL teachers around the world, without whom this project would remain only an idea.

References

Wielicki, B. A., B. R. Barkstorm, E. F. Harrison, R. B. Lee III, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment. Bull. Amer. Meteor. Soc., 77, 853–868.

Kudos

The MODIS Near Real Time Processing Team has been awarded the NASA Group Achievement Award for establishing a processing and delivery system providing selected biogeophysical products to operational weather centrals. As a direct result of their outstanding interagency cooperation, products enabled by the Near Real Time effort are used to support Operation Enduring Freedom. The team consists of individuals from Government and contractor organizations including NASA Goddard Space Flight Center, NOAA's NESDIS: National Environmental Satellite, Data, and Information Service, the Air Force Weather Agency (AFWA), the Fleet Numerical Meteorology and Oceanography Center (FNMOC), the Naval Oceanographic Office (NAVOCEANO), the Naval Research Laboratory (NRL), and participants from several contractor companies.

The Earth Observer staff and the entire Earth Science community wish to congratulate this team on its outstanding accomplishments.

Global Garden Gets Greener

— Rebecca Lindsey, relindsey@earthlink.net, Science Systems and Applications, Inc.

Published on the Earth Observatory Website: earthobservatory.nasa.gov/Study/GlobalGarden/

Leaving aside for a moment the deforestation and other land cover changes that continue to accompany an ever-growing human population, the last two decades of the 20th century were a good time to be a plant on planet Earth. In many parts of the global garden, the climate grew warmer, wetter, and sunnier, and despite a few El Niño-related setbacks, plants flourished for the most part.

Numerous small-scale studies over the past 20 years suggested that patches of the garden were getting greener, but that trying to paint a global picture would be a monumental project. A team of eight scientists from across the country worked for almost a year and a half to pull together satellite data on vegetation and ground- and satellite-based climate observations. Their results show us not only how vegetation productivity has changed during two of the warmest decades in the record books, but they also reveal which of the many factors that influence plant productivity have been most important in those changes.

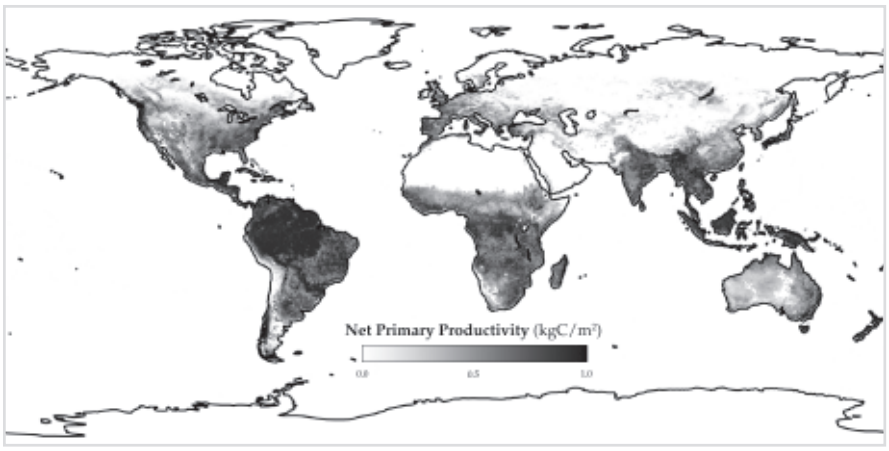
When scientists talk about productivity, they are specifically talking about how much carbon ends up stored in the living biomass—roots, trunks, and leaves of plants—after they tally up carbon gains through photosynthesis and carbon losses through respiration. This tally of gains minus losses is called "net primary production." Scientists estimate net primary production by observing how leafy vegetation is and how much sunlight it is absorbing, which can both be measured by satellite. Combined with climate data on rainfall, temperature, and available radiation, the satellite observations reveal where carbon intake increased—and biomass grew—across the globe.

"Between 1982 and 1999, 25% of the Earth's vegetated area experienced increasing plant productivity—a total increase of about 6%," says Ramakrishna Nemani, the study's lead scientist. "That increase occurred mainly in the tropics, and secondarily in high northern latitudes. What's interesting about our results is that they show how the increase in each of these regions is due to a different climate factor. In the tropics, Nemani and his colleagues discovered that the increase in productivity was caused by lack of clouds and increased Sun exposure, while in the northern latitudes, it was mainly due to increased temperatures and, to a lesser extent, water availability.

Increases in productivity are important in a practical sense, since plant biomass is the food and fuel for all animals—including humans—on the planet. It's also important in the way that everything related to carbon has become important in recent years. Scientists and environmental policy decision makers across the world want to know what is happening to all the carbon in the carbon dioxide pumped into the atmosphere through fossil fuel and biomass burning, such as forest fires or firewood used as fuel. If carbon dioxide is "food" for plants, maybe more of it in the atmosphere caused plants to grow better.

"Experiments conducted in places like the U.S and Europe, where scientists pumped extra amounts of carbon dioxide gas into forests, did seem to show that such 'carbon dioxide fertilization,' caused plants to grow better—up to a point," says Nemani. "But this didn't go on year after year. Most people agree that a doubling of carbon dioxide could increase plant growth between 0% and 25% depending on resource limitations such as soil nutrition. With the 9% increase in carbon dioxide that occurred between 1980 and 2000, even the upper limit cannot explain the productivity increases in the Amazon." Clearly, carbon dioxide fertilization couldn't be solely responsible for the change; climate change must be playing a role as well.

To reach these conclusions, Nemani and colleagues from Scripps Institute of Oceanography, University of Montana, NASA's Goddard Space Flight Center, and Boston University used global climate data from the National Center for Environmental Prediction to determine the relative importance for various locations of the three key variables that influence plant growth: temperature, water availability, and sunlight. They indexed areas based on which of those factors most limited plant growth across the Earth. Lack of



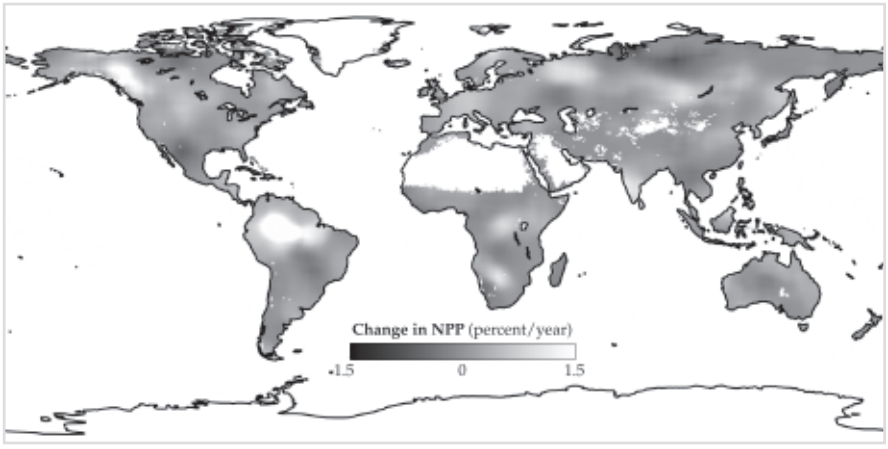
Nearly 20 years of satellite observations of net primary productivity reveal the seasonal and yearly cycles of Earth's vegetation. This image shows the net primary productivity during the month of December 1999. More subtle vegetation patterns include a decrease in productivity at high latitudes of the Northern Hemisphere following the eruption of Mt. Pinatubo in 1991, and global-scale decreases in productivity during El Niño events. (Image based on data provided by the University of Montana NTSG)

sufficient water limits the growth of 40% of Earth's vegetation, temperature limits 33%, and lack of sufficient sunlight limits the remaining 27%. Of course, these factors overlap in some cases; for example, both cold winters and dry summers limit plant growth in the western U.S.

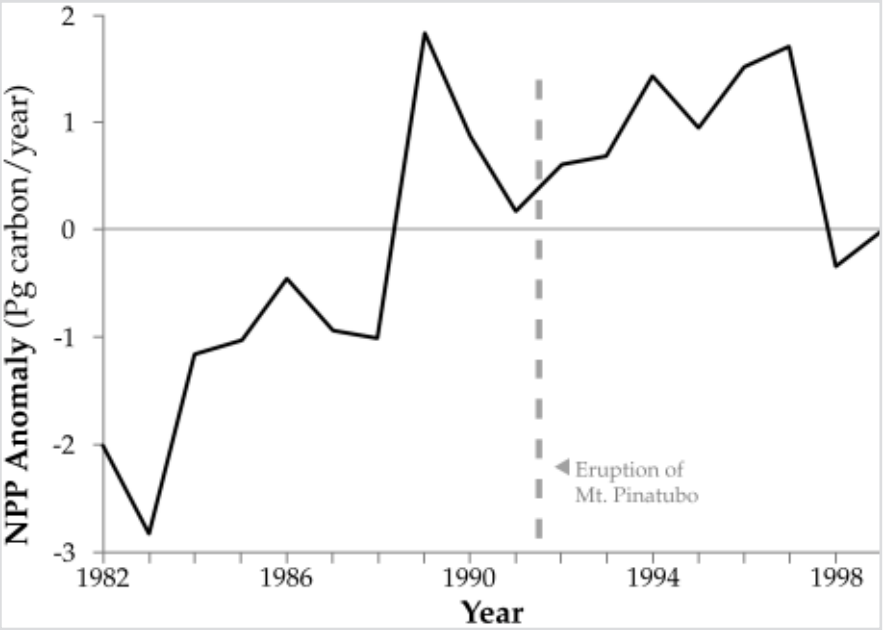
After identifying key regulators of plant growth across the globe, Nemani and his colleagues then looked at how those climate conditions changed over the past two decades. They compared these changes to satellite-based maps of vegetation collected by the National Oceanic and Atmospheric Administration's series of AVHRR (Advanced Very High Resolution Radiometer) sensors. The digital satellite observations were processed and refined into maps by NASA's Global Inventory Modeling and Mapping Studies project headed by Compton Tucker at Goddard Space Flight Center. It was the comparison of satellite-based vegetation and climate data that allowed them to pinpoint decreased cloudiness in the tropics as the main driver of increased productivity, something that hadn't been seriously considered before.

The group of scientists who did this study have been working together off and on for many years. Nemani worked with University of Montana colleague Steve Running in 2001 on a study of whether good vintages could be scientifically tied to climate variation, and found that they could—even suggesting that good vintages might be predicted by observing sea surface temperatures off California and winter climate. Since the late 1990s, Ranga Myneni of Boston University has published a series of papers in collaboration with some of the same researchers on the impact of the last two decade's climate changes on Northern Hemisphere vegetation, describing how lack of snow cover and warmer temperatures are lengthening the Northern Hemisphere growing season by almost two weeks and increasing productivity. After all these years of working together, it was natural for them to pool their expertise and interests to "go global" with the study of climate and vegetation.

Nemani says it would be nice if the next decade were as favorable for plants as the past two seem to have been. "Unfortunately, we have no way of knowing yet whether climate changes will continue to have a positive effect on vegetation productivity," he cautions. "India, for example, got a blessing from nature during the



Changes in rainfall, temperature, and sunlight between 1982 and 1999 increased the overall productivity of land plants by 6 percent. This map shows productivity increases in white, while decreases are shown in black. Productivity increased the most in tropical regions, where climate change resulted in fewer clouds and more sunlight. [Image based on data provided by the University of Montana Numerical Terradynamic Simulations Group (NTSG)]



Global primary productivity has been rising since 1982. In contrast to the long-term upward trend, El Niño years and the eruption of Mount Pinatubo occasionally decreased overall plant growth. (Graph based on data provided by the University of Montana NTSG)

1990s. For 100 years, there has been a strong relationship between El Niño and the monsoon season that brings rain to India and Southeast Asia; El Niño events interrupt the monsoon and create drought. In the 1990s, that relationship broke down, and the monsoon rains came despite a severe and persistent El Niño." As a result, while much of the globe saw a decrease in productivity during El Niño events, India was one of the places where productivity increased. Whether the region can count on such a lucky break this decade can't be predicted.

That unpredictability means that in all likelihood, we shouldn't be dismissing our worries about carbon dioxide in the atmosphere or congratulating ourselves on our green thumb just yet. "Humans claim about half of all the net primary production on Earth," says Myneni. "Productivity may have increased 6 percent in the last 18 years, but human population has increased by over 35 percent over that same time. One half of a 6% increase in the net productivity compared to a 35% increase in population means that these net primary productivity changes have not improved global habitability in any significant way."

"This global study is a good foundation," concludes Nemani. "It helps us decide where on the globe we should look more closely at what is happening with Earth's vegetation. But as far as the whole carbon cycle goes, this is only part of the picture. We didn't look at how climate changes might have influenced other ecosystem processes that release carbon dioxide back into the global system." Warmer temperatures could increase the rate at which soil microbes decompose organic matter and release carbon dioxide. In the tropics, lack of cloud cover might temporarily increase productivity until the increased evaporation caused by all that extra sunlight makes water availability more important. Productivity could drop just as easily as it has risen. What this study does tell is that, so far, climate change is making the Earth's vegetation more productive, but the impact is small compared to how quickly the human population is growing. This knowledge could be a key piece of information for societies around the world as they cultivate the global garden through agriculture, natural resource management and environmental policy.

Earth Science Education Update

— *Ming-Ying Wei, ming-ying.wew-1@nasa.gov, NASA Headquarters*
— *Diane Schweizer, diane.schweizer@nasa.gov, NASA Headquarters*
— *Theresa Schwerin, theresa_schwerin@strategies.org, Institute for Global Environmental Strategies*

A REASoN to Focus on Earth Science Education

NASA has selected 41 proposals in response to a cooperative agreement notice known as "REASoN" - the "Research, Education, and Applications Solutions Network." The selected proposals will help us to understand and protect our home planet while inspiring our next generation of explorers through the use of the agency's wide range of Earth science resources. Six of the selected proposals are in Education:

Steven Ackerman, University of Wisconsin Madison, *Satellite Observations in Science Education*

Lin Chambers, NASA Langley Research Center, *Extending NASA Earth Science Data Use to the K-12 and Citizen Scientist Communities*

Liping Di, George Mason University NASA EOS Higher-Education Alliance, *Mobilization of NASA EOS Data and Information Through Web Services and Knowledge Management Technologies for Higher-Education Teaching and Research*

John Pickle, Boston Museum of Science, *Measuring Vegetation Health*

Patricia Reiff, Rice University, *Immersive Earth: Teaching Earth Science by Fulldome Experiences and Hands-On Exhibits*

Glen Schuster, U.S. Satellite Laboratory, *Project VIEW* (Virtual Interactive Environmental Worlds)

These proposals will facilitate the use of NASA Earth science capabilities to ensure scientific successes that serve scientists studying Earth system science, decision-makers of federal agencies and other organizations, and society at large. A complete listing of selected proposals is available on the Internet at *research.hq.nasa.gov/code_y/archive.cfm*. Click on 2003 to find the full REASoN Cooperative Agreement notice (CAN) selection results.

NASA CONNECT™: Earth Science Broadcasts In 2003-2004

NASA CONNECT™ is a research, inquiry, and standards-based series of FREE integrated mathematics, science, and technology instructional education programs for students in grades 6-8. Each program has three components: (1) a 30-minute television broadcast, which can be viewed live or taped for later use; (2) an educator guide describing a hands-on activity; and (3) an interactive web activity which provides educators an opportunity to use technology in the classroom setting. These three components — television broadcast, educator guide, and web activity — are designed as an integrated instructional package.

The following are Earth science-related shows planned for the 2003-2004 season. For more information, visit *connect.larc.nasa.gov*

Virtual Earth

Starts airing: Thursday, October 16, 2003

NASA researchers and scientists use data analysis and measurement to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.

Mathematics concepts: Data Analysis and Measurement

Science concepts: Earth as a System

NASA Research: Earth System Science

The "A" Train Express

Starts airing: Thursday, May 20, 2004

Take a ride on the "A" Train Express. NASA researchers and scientists use satellites and problem solving to improve weather prediction and our understanding of aerosols and clouds.

Mathematics concepts: Problem Solving

Science concepts: Weather and Meteorology

NASA Research: CALIPSO Satellite, CloudSat Satellite

NASA Announces 2003-2004 Student Competitions

Posters announcing the 2003-2004 NASA Student Involvement Program (NSIP) competitions for K-12 students are now available. Opportunities include Earth-focused research, planetary-mission design, communicating the story of flight in print or on videotape, and creating experiments for NASA launch. Easily adapted to local curricula, the competitions support science, math, geography and technology standards. All participants receive NSIP certificates. Awards include plaques, medals, NASA ceremonies at schools, Space Camp scholarships, trips for high school students and their teachers to the National Symposium and/or Student Flight Weeks. Posters and additional competition information are available on the NSIP website at *education.nasa.gov/nsip*.

Special Session on Geoscience Education Assessment at Fall AGU Meeting

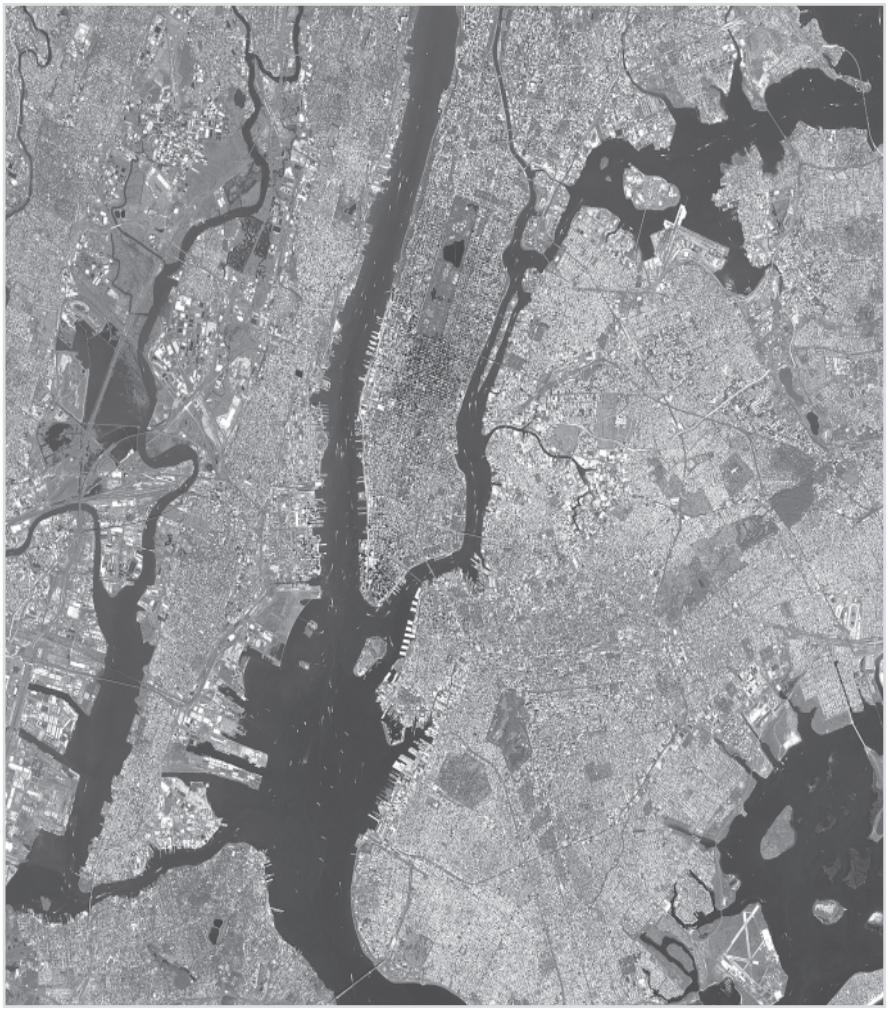
Abstracts Deadline: September 4, 2003

A variety of innovative geosocience education tools and approaches exist that facilitate learning about global and local environmental issues in colleges and universities, yet little emphasis has been put on their comprehensive assessment, despite the clear need and often requirement to demonstrate the impact these techniques have on student learning.

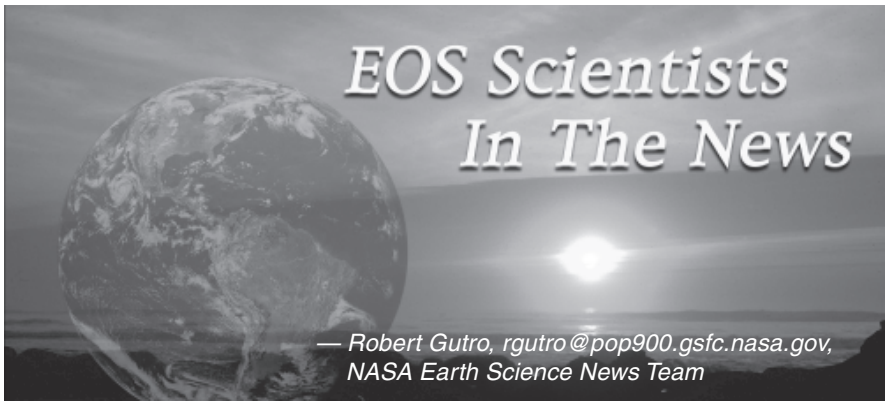
A special session is planned for the Fall Meeting of the American Geophysical Union (AGU) to showcase the strategies that geoscientists are developing and applying to assess the different teaching tools and approaches they use. The session conveners are soliciting abstracts for proposed presentations during this session. The full session description is available at: *www.agu.org/meetings/fm03/*sessions.shtml (click on the link for Education and Human Resources and scroll down to "ED10 Assessment of Geoscience Education Tools and Approaches."

For more information, contact the session conveners: Catherine Gautier, UC Santa Barbara, 805-893-8095 or *gautier@icess.ucsb.edu*, and Diane Schweizer, NASA Headquarters, *Diane.Schweizer@nasa.gov*. The online submission form for abstracts will be available from the AGU WWW site beginning on August 1; Abstracts are due no later than September 4.

The AGU Fall Meeting will be held December 8-12, San Francisco, with several other sessions planned on wide-ranging topics related to geoscience education. For the full list of approved education sessions, go to: *www.agu.org/meetings/fm03/sessions.shtml#ED*.



This satellite image shows greater New York City. The Island of Manhattan is jutting southward from top center, bordered by the Hudson River to the west and the East River to the east. (North is straight up in this scene.) In the middle of Manhattan, Central Park appears as a long rectangle running roughly north-south with a large lake in the middle. Also visible are parts of Staten Island (bottom left corner) and Long Island (lower right). This image was acquired on Sept. 8, 2002, by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) aboard NASA's Terra satellite.



— Robert Gutro, rgutro@pop900.gsfc.nasa.gov,
NASA Earth Science News Team

Special Announcement: AIRS Team Member to Receive Award, August 2003. It has recently been announced that Mitch Goldberg and Gene Legg of the AIRS Science Team and NOAA will be receiving a Department of Commerce Gold Medal for their work in providing AIRS/AMSU/HSB data to the National Weather Service.

In Tropics, Forests Are Cool But Croplands Are Hotter, Aug. 21, *Der Wissenschaft* (Germany), *NewsNow* (UK), A study of Santa Cruz, Bolivia, by Lahouari Bounoua (NASA/GSFC) and Ruth DeFries (University of Maryland College Park) using NASA satellites and computer models, reported that cutting down tropical forests and converting grasslands to crops may inadvertently warm those local areas.

El Niño's Surprising Steady Pacific Rains Can Affect World Weather, Aug. 20, Brightsurf.Com, Der Wissneschaft (Germany), *Environment News Service Sciencedaily Spaceref* - **Courtney Schumacher** and **Robert Houze**, (University of Washington) noticed El Niño events produce more of a steady rain in the middle of the Pacific Ocean.

U. of Colorado to Study Changes in Earth's Glacier Systems, Aug. 12, *Brightsurf.com* - **Richard Armstrong** and researchers at the National Snow and Ice Data Center at the University of Colorado at Boulder will receive $1.8 million from NASA to compile an online database of the world's glaciers.

Researchers Find Antarctic Lake Water Will Fizz Like a Soda, Aug. 12, *Brightsurf.com* - **Chris McKay** (NASA/Ames) said water released from Lake Vostok, deep beneath the south polar ice sheet, could gush like a popped can of soda if not contained, opening the lake to possible contamination.

How Cities Make Their Own Weather, August 11, *TIME Magazine* - **Marshall Shepherd** (NASA/GSFC) is quoted in this article about islands of urban heat and the effect they have on weather.

NASA Satellite Improves A Winter Storm Forecast Looking At Ozone, Aug. 7, *Brightsurf*, *Der Wissenschaft* (Germany), *Spacedaily* - **Kun-Il Jang** and **Xiaolei Zou** (both of Florida State University) added ozone measurements from a NASA satellite into computer weather forecast models and improved several factors in a forecast of a major winter snowstorm that hit the United States in 2000.

Cooperation Earth: U.S. Hosts 'Earth Observation Summit, July 31, *Christian Science Monitor* – **Ghassem Asrar** (NASA HQ Office of Earth Science) is quoted in this article about a meeting of representatives of 35 countries and 22 multilateral organizations to start work on integrating systems to monitor the weather, oceans, land use and climate change.

NASA Observations Indicate the First Stage of Ozone Layer Recovery, July 29, *Atlanta Journal-Constitution*, *SpaceRef.com*, *Scientific American.com*, *ABC News*, *USA Today*, *National Geographic.com*, *CNN*, *Nature.com*, *Environmental News Network*, *New Scientist.com*, *Japan Times Online*, *New York Post Online*, and many other media outlets - **Mike Newchurch** (University of Alabama) and **Joe Zawodny** (NASA LaRC) discuss how data from HALOE on UARS, SAGE I and SAGE II provide the first evidence the rate of ozone depletion in the Earth's upper atmosphere is decreasing.

'Potato' Earth's Deep Secrets, July 24, *AP*, *BBCnews.com*, *DiscoveryChannel .com* - **Michael Watkins**, **Victor Zlotnicki** and **Lee-Lueng Fu** (all NASA JPL), **Byron Taplley** (University of Texas) were quoted in articles about the GRACE satellite producing the most detailed gravity map of the Earth, to help understand ocean movements.

Scientists Ponder Sun's True Impact on Earth's Climate, July 24, *ABCnews .com*, *Christian Science Monitor* - The Sun's influence on changes in climate has been a topic of hot debate among physicists, astronomers, and more Earth-oriented climate researchers. **Robert Cahalan** (NASA/GSFC), **Drew Shindell** (NASA/GISS) and **Judith Lean** (U.S. Naval Research Lab) were quoted.

As World Swelters, Some Rare Cool Spots, July 23, **CNN**, *Reuters* - With the world sweltering through one of the

hottest years on record, some icy bastions have been getting frostier in defiance of global warming. **Joey Comiso** (NASA/GSFC) explained how warmer oceans lead to more snow in colder areas.

NASA Earth Science Update: Cool "Eyes" Above Help Track Hot Fires Below, July 22, *CBS Network News*, *Environment News Service*, *Voice of America Radio*, multiple television stations – **Chris Justice** (University of Maryland), **Vince Salomonson** (NASA/GSFC), and **Tom Bobbe** (USDA Forest Service) were on a panel, broadcast on NASA-TV for the media, discussing NASA's tools for fire monitoring moderated by Marshall Shepherd (NASA HQ).

African Dust Brings Drought, Rain Across Atlantic, July 15, *Associated Press* - Dust from the Sahara Desert in Africa may modify clouds and rainfall both in Africa and across the tropical North Atlantic as far away as Barbados, **Natalie Mahowald** (National Center for Atmospheric Research) and **Lisa Kiehl** (University of California at Santa Barbara) in their study using data from NASA satellites, ground measurements, and computer models.

Satellites See Lightning Strikes in Ozone's Origins, July 14, *Spaceflight Now*, *Associated Press*, E*nvironmental News Service*, *Spaceref.com* – **David Edwards** (National Center for Atmospheric Research) and other NASA-funded scientists are using four satellites to tell where low-level ozone pollution comes from and whether it was manmade or natural.

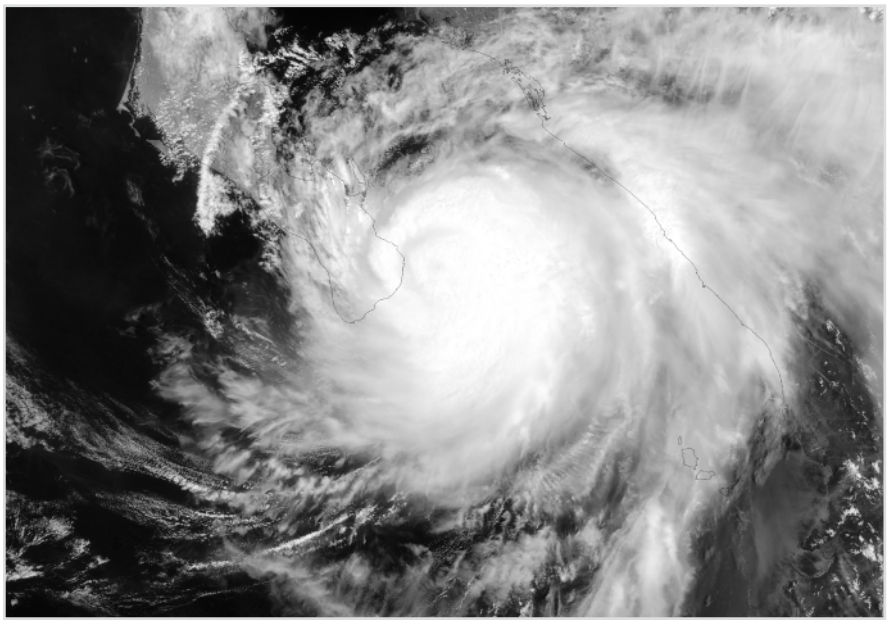
Scientists Study Air 14 Miles out on Chesapeake Light, July 12, *The Virginian-Pilot* - NASA scientists find success in the use of the Chesapeake Light for validating readings from the Aqua satellite.

NASA Satellites Help Track Crops in Iowa, July 11, *Associated Press* – **Mark Westgate** of Iowa State University said scientists are using images from satellites and airplanes to track the health of corn and soybean fields, predict yields and see whether pollen from biotech crops will contaminate other fields.

NASA Funds Research on Soft-Shell Crabs, July 10, *Durham Herald Sun* - The National Science Foundation and NASA are supporting **Jennifer Taylor's** (University of North Carolina) research to find out what keeps soft-shell crabs from collapsing when they shed their shells.

NASA Designed Video Stabilizer Used to Fight Crime, July 10, *KTVT-TV Dallas, TX* and *WTTG-TV, Washington, DC* – **Paul Meyer** (NASA/MSFC) was interviewed about his invention that stabilized video for satellite imagery, now being used by law enforcement agencies.

NASA Research Helps Highlight Lightning Safety Awareness Week, June 19, *Environmental News Network*, 20 Television stations, 4 Newsradio stations - **Dennis Boccippio**, **Steve Goodman** (both NASA/MSFC) were interviewed and quoted on television, radio, and websites on this story about NASA's research on lightning.



The MODIS instrument onboard NASA's Terra spacecraft captured this image of Hurricane Ignacio as it was bearing down on the southern tip of Baja.

At the time this image was taken, Ignacio was packing winds near 105 mph, making it a Category 2 storm on the Saffir-Simpson scale. On Monday, Aug. 25, 2003, the National Hurricane center issued a warning that the storm could produce 20 inches or more of rain to fall in the southern baja region and said the rains could cause "life-threatening" flash floods and mudslides.

Image courtesy Jeff Schmaltz, MODIS Land Rapid Response Team at NASA GSFC

Getting to Know ESTO

— Philip Larkin, plarkin@gst.com, ESTO Office, Goddard Space Flight Center

You may have heard the acronym before. You may even know that ESTO is located at Goddard Space Flight Center. But, chances are, you may not have a clear idea of what ESTO does.

ESTO, the Earth Science Technology Office (Code 407), was created in 1998 to lead strategic technology development and planning for the Earth Science Enterprise. Although ESTO is physically located at GSFC, it is a Level 2 office and performs an Earth Science Enterprise headquarters function.

NASA's first Earth Science Biennial Review in 1997 recommended that missions be implemented with shorter development times using the best available technologies. That recommendation produced a dramatic shift in process: science objectives, not mission objectives, drive technology development; technology, in turn, expands mission horizons; and missions evolve from the convergence of science objectives and technology availability. ESTO was established to develop and nurture the technologies that drive this new process.

Through flexible, science-driven technology strategies and a competitive selection process for highly specific technologies, ESTO has developed a broad portfolio of emerging technologies. Currently, ESTO is supporting the development of 174 technologies at over 50 institutions (universities, corporations, and NASA centers) nationwide. Many ESTO technologies are being used in Earth Science missions, as well as Code S and Code M missions, and commercial applications to benefit society at large.

There are two primary areas of technology development at ESTO: Observation and Information. In each of these, ESTO plans investments, develops new technologies, and identifies infusion paths for successful deployments in future measurements. The Instrument Incubator Program (IIP) and Advanced Component Technologies (ACT) program lead the development of new and innovative technologies that lead to smaller, more powerful, less costly observation tools.

The Advanced Information Systems Technology Program (AIST) and the Computational Technologies Program (CT) work toward a variety of goals within information technologies. From sensor web networking and on-board processing to terabyte acquisition and modeling interoperability, these two programs make observations useful and help to turn data into knowledge.

Technology requirements are derived by ESTO in response to science measurement goals. ESTO recently developed a knowledge management database, the Earth Science Integrated Planning System (ESTIPS), to catalog technology needs as well as communicate the underlying science questions. The database is available at: *esto.nasa.gov/estips*

By identifying technology needs from science requirements, regularly assessing the maturity of technologies within the portfolio, and leveraging investments through creative partnerships, ESTO will continue to enable future science applications far into the 21st century. To learn more about ESTO and its programs go to: *esto.nasa.gov*

EOS Science Calendar

September 23 - 25

HDF & HDF-EOS Workshop VII , Silver Spring, MD. Call for abstracts. Contact: Richard Ullman, Richard.E.Ullman@nasa.gov. URL: hdfeos.gsfc.nasa.gov

September 23 - 25

CERES Science Team Meeting, Hampton, Va. Contact: Shannon Lynch, s.m.lynch@larc.nasa.gov.

September 30 - October 3

Aura Science Team Meeting, Pasadena, CA. Contact: Anne Douglass, Anne.R.Douglass@nasa.gov.

October 15

SEDAC User Working Group meeting, Montreal, Canada. Contact: Robert Chen, bchen@ciesin.columbia.edu.

October 29-31

MODIS Science Team Meeting. BWI Airport Marriott. Contact: Barbara Conboy. Email: Barbara.L.Conboy@nasa.gov.

December 4-6

SORCE Science Meeting, Sonoma, CA. URL: lasp.colorado.edu/sorce/Dec03ScienceMeeting.html. Contact: Vanessa George, vanessa.george@lasp.colorado.edu.

Global Change Calendar

2003

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/

2004

January 11-15

American Meteorological Society Annual Meeting, Seattle, WA. URL: www.ametsoc.org.

February 24-27, 2004

8th Specialist Meeting on Microwave Radiometry and Remote Sensing Applications, Rome, Italy. URL: www.microrad04.org

March 22-23

Seventeenth Annual Towson University GIS Conference, Towson University, Baltimore, MD. Contact: Jay Morgan, Email: jmorgan@towson.edu, URL: cgis.towson.edu/tugis2004

May 23-28

ASPRS Annual Conference, Denver, CO. URL: www.asprs.org/denver2004

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The Earth Observer Staff:

Executive Editor:	Charlotte Griner (charlotte.griner@gsfc.nasa.gov)
Technical Editors:	Bill Bandeen (bill_bandeen@ssaihq.com)
	Jim Closs (jim.closs@gsfc.nasa.gov)
	Renny Greenstone (rennygr@earthlink.net)
	Tim Suttles (4suttles@bellsouth.net)
	Alan Ward (alan_ward@ssaihq.com)
Design and Production:	Alex McClung (alexander_mcclung@ssaihq.com)
Distribution:	Hannelore Parrish (hannelore_parrish@ssaihq.com)

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