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EDITOR'S CORNER

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EOS Senior Project Scientist

I'm proud to announce that the International Academy of the Digital Arts and Sciences has selected two NASA Web sites for top honors in their respective categories. The NASA Home Page (at *www.nasa.gov*), managed by Brian Dunbar and his team at NASA Headquarters in Washington, D.C., won the Webby in the "Government & Law" category. And NASA's Earth Observatory (at *earthobservatory.nasa.gov*), managed by David Herring and his team at Goddard Space Flight Center in Greenbelt, MD, won the Webby in the "Education" category.

Additionally, both sites won "People's Voice Awards" for their respective categories. In keeping with the spirit of the Web's capacity for global interactivity, the People's Voice Award is determined by a popular vote in which anyone in the world can vote for their favorites in each of the Webby's thirty categories.

The Webby is the most coveted award by the on-line community (visit *www.webbyawards.com* for details). Congratulations to the development teams for these two outstanding internet resources, and be sure to check them regularly for new informative and stimulating content.

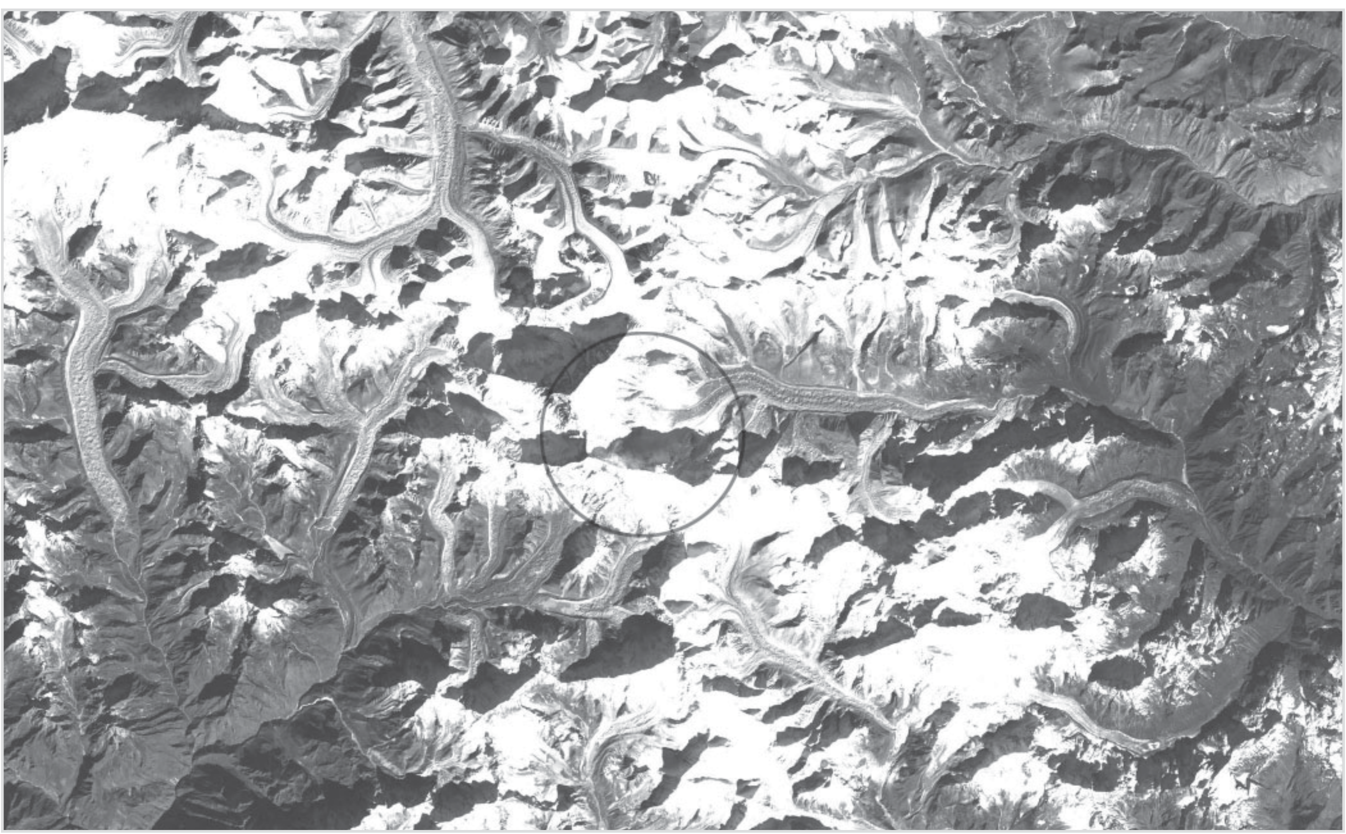
On a somewhat less celebratory note, the Landsat 7 mission is experiencing a problem with the Enhanced Thematic Mapper + (ETM+) multi-spectral scanning instrument. On May 31 the scan line corrector for the instrument encountered an anomaly, and operations have been halted pending a resolution. The scan line corrector adjusts the line-of-sight of the ETM+, tracing contiguous scan lines orthogonal to the satellite's path. Without the scan line corrector, the ETM+ scan mirror traces a zig-zag pattern across the field-of-view resulting in gaps between scan lines.

Continued on page 2

An anomaly tiger team, comprised of engineers from NASA, USGS, and the ETM+ manufacturer, Santa Barbara Remote Sensing, is investigating the cause before taking any action to restart the scan line corrector.

The Landsat series of satellites has been a keystone in land remote sensing since the original Earth Resources Technology Satellite (ERTS-1) was launched in July of 1972. The second generation of Landsat satellites began with the launch of Landsat 4 in 1982, which carried the new Thematic Mapper (TM) instrument, with greater spatial and spectral resolution than MSS. ETM+ was launched on Landsat 7, and is capable of even greater resolution. As a result, the Landsat series of satellites has produced an extremely valuable continuous data record of the Earth's land surface and coastal regions for over 30 years.

There will be a special Earth Showcase press conference in July that will focus on wildfire monitoring by NASA Earth observing satellites. EOS investigator Chris Justice at the University of Maryland, the MODIS Rapid Response Team, members of U.S. Forest Service and NASA will participate in this "Meet the Press" event. The animation on wildfires produced by the Scientific Visualization Studio at Goddard Space Flight Center will be featured at this event. This is just one of several Earth science applications programs developed within the Enterprise, and demonstrates the real socio-economic benefits of NASA's Earth science program.



This image of Mt. Everest (center, circled) was acquired by Landsat 7's Enhanced Thematic Mapper plus (ETM+) sensor on January 5, 2002. On May 29, 1953, Edmund Hillary, from New Zealand, and Tenzing Norgay, from Nepal, became the first humans to successfully climb to the peak of Mt. Everest, the tallest mountain in the world. Data for this image was provided by the Landsat 7 Team at NASA's Goddard Space Flight Center.

Minutes of the March 2003 Aura Science Team Meeting

— *Anne Douglass, Anne.R.Douglass@nasa.gov, Deputy Aura Project Scientist, NASA Goddard Space Flight Center*

An Aura Science Team meeting was held March 18 – 21, 2003 in Greenbelt, MD. Four of the working groups (validation, data systems, aerosols, and education and outreach) met on March 18, and the full science team convened March 19-21. The Aura Project Manager, **Rick Pickering**, provided an overview of the status of Aura, stressing that Aura integration continues to benefit from experience with Aqua. The project remains focused on a launch date in January 2004. As of the March meeting, three of the four instruments, the Ozone Monitoring Instrument (OMI), High Resolution Dynamics Limb Sounder (HIRDLS), and the Microwave Limb Sounder (MLS)) had been delivered. Modifications to the schedule will accommodate late April delivery of the Tropospheric Emission Spectrometer (TES). **Carolyn Dent** summarized results and plans for spacecraft interface testing. The first tests have included a collection of simulated data. Future tests will simulate normal daily activities (including ground system contacts and Tracking and Data Relay Satellite [TDRS] contacts) and contingency operations in case of emergency. **Glen Iona** provided a brief summary of the Mission Planning Review that was held in February for the Earth Science Data and Information System (ESDIS) project.

John Gille and **John Barnett**, HIRDLS co-Principal Investigators, reported that an improved retrieval procedure will take into account the line-of-sight temperature gradient along the limb. HIRDLS calibration was completed in December 2002. The signal-to-noise in the instrument exceeds requirements, and it may be possible to include an additional vertical scan (7 instead of 6) in the across-track direction within 4° of latitude along track. With such low noise it is possible to complete the scans more rapidly.

Joe Waters (MLS Principal Investigator) reported that MLS noise is also lower than specifications. The precision estimates provided so far are based on maximum allowable noise, thus performance on orbit may be better than presently advertised. Changes to the MLS instrument, including replacement of a whisker diode tripler with a planar diode tripler, will be coordinated with activities involving TES to minimize impact on the spacecraft schedule.

Bert van den Oord represented **Pieternel Levelt** (OMI Principal Investigator). Synthetic OMI data are being produced using data from the Global Ozone Monitoring Experiment (GOME) instrument to test the processing system. The OMI team recognizes that the NO_2 retrieval relies on the *a priori* information, and plans to develop retrieval methods using constituent assimilation.

Mike Gunson, deputy to **Reinhard Beer** (TES Principal Investigator), gave a time history for performance and modifications of TES during recent tests that revealed problems with the beam-splitter alignment. TES was in calibration at the time of the science team meeting. TES signal-to-noise needs improvement, and options such as bandpass filtering are being investigated.

Reports from Working Groups

The Data System Working Group (DSWG), chaired by **Scott Lewicki** ,addressed issues that are common to all of the Aura Instrument Teams including data product formats, science system interfaces and testing, quality assessment, tools, and end-user interests. At the last meeting, the team

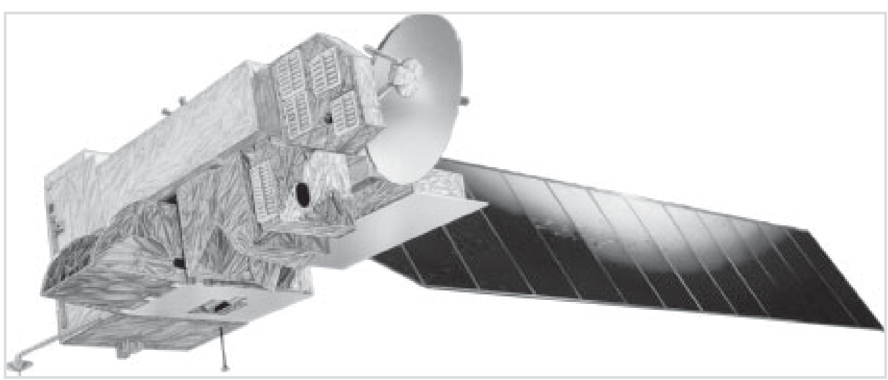


Figure 1: The Aura Satellite

expanded on the current HDF-EOS Aura File Format Guidelines to specify data types and field names and laid the groundwork for comparison of Level 2 Aura products, including the use of a Dataset Validator tool. They also heard reports from the Earth Science Data and Information System (ESDIS) on science-system interfaces, secure data transfer, and ground-system tests (Mission Operations Science System [MOSS]). Additional topics included the development of an EOSDIS Core System (ECS) Metadata editor and the use of IDL and other tools for examining products in HDF-EOS5.

The Education and Public Outreach Working Group (**Ernest Hilsenrath**, chair) reported on recent activities with its partners in getting the word out about Aura to peers, students and the general public. The American Chemical Society's *ChemMatters* magazine, which goes to 30,000 high school teachers, has started on its 3rd dedicated issue on Aura and atmospheric chemistry. This issue will be released in conjunction with "Chemistry Week." The Smithsonian National Museum of Natural History is working with NGST to display a half-scale model of the Aura spacecraft as part of the Atmospheric Chemistry exhibit to open in Summer 2004.

A Global Learning and Observations to Benefit the Environment (GLOBE) workshop was held to familiarize teachers with Earth science and how measurements tropospheric ozone and aerosols, made by students as part of GLOBE, could provide results for science and validation. Visit *earthobservatory.nasa.gov* for recent articles on atmospheric chemistry.

The Aerosol Working Group (**Steven Massie**, chair) considers issues concerning aerosols that are common among the Aura instruments. The MLS cloud-ice retrieval will generate ice water content values greater than 0.005 gm/m^3 at 100 hPa (report by Dong Wu presented by Steven Massie). If HIRDLS performs as expected it will retrieve ice water content on the order of 0.0001 gm/m^3. This leaves a data gap for cirrus sizes that will not be measured by HIRDLS or MLS. **Omar Torres** gave an overview of the Total Ozone Mapping Spectrometer (TOMS) data record and aerosol detection capabilities, including detection of desert dust over bright reflective desert regions. These same capabilities are expected for OMI. Data from the TOMS and OMI instruments should be combined to produce a continuous record of tropospheric aerosol over the past 25 years. **Alyn Lambert** presented an overview of the development of the HIRDLS aerosol retrieval. The retrieval has been applied to sulfate aerosol loading for conditions in which the aerosol amount is minimal (current conditions). Finally, Steve Massie is contacting those in the volcanology community to find out how the Aura teams can be contacted within hours of a major volcanic eruption.

B. Bojkov and **E. Hilsenrath** presented a proposal for an Aura Correlative Data Center (ACDC) to the Aura Validation Working Group on Tuesday and to the entire Aura Science Team on Wednesday. The data center's planned functions and implementation were discussed. Agreement was reached on the role of the ACDC, the correlative data format (HDF-4 and HDF-EOS5) that will be implemented, and the set of tools that will be made available to the validation teams. A formal proposal for the ACDC has been submitted to HQ for funding.

Validation

The science team has paid great attention to the development of the validation plan for Aura. The challenge from the Snowmass (1999) meeting to the Aura Science Team is that validation data beyond routine observations be obtained within the context of science missions.

Mark Schoeberl presented an overview of Aura validation and its implementation plan including the development of ACDC and a trailer facility. This overview illustrated the contributions of data from ground-based networks, other satellites, and special observations. These special observations include data from balloon instruments and from aircraft missions.

Lucien Froidevaux presented a summary of the March 18 Validation Working Group meeting. This meeting emphasized the routine datasets that will be used in Aura validation, including meteorological datasets, sonde data, ground-based data, data from airborne instruments that are flown on commercial aircraft, and data from other satellites. Plans were presented (B. Bojkov) for a central location for correlative data as part of the ACDC. The correlative datasets, liaisons who assure that the data is available, and any issues associated with the datasets are summarized in tables that can be found at *eos-aura.gsfc.nasa.gov/index.html*. Several airborne missions have been identified between 2004 and 2006 that are expected to play an important role in the validation of Aura data. These include INTEX/E (midlatitudes, summer 2004), Tropical Composition and Climate Coupling (TC^3)/Cirrus Regional Study of Tropical Anvils and Cirrus Layers (CRYSTAL — tropics, NH winter 2004/5, NH summer 2005), INTEX/W (midlatitudes, spring 2006), and the Polar Auroral Plasma Physics Spacecraft (POLAR — high northern latitudes, winter 2006). The instrument teams are asked to clarify their needs for aircraft mission data. This two-part action item requires the teams to specify the types of measurements that would be most useful (e.g., MLS and HIRDLS both desire along-track profiles for 800 – 1000 km), and also to identify any needs for aircraft data that are not met by these missions.

Daniel Jacob reported briefly on a field experience during TRACE-P to provide CO profiles for validation of observations by Measurements Of Pollution In The Troposphere (MOPITT) on Terra. Validation was not a priority for any flight, but fortunately 50% of the planned flights provided an opportunity for coincidence with Terra overpasses, and flight plans were designed to obtain correlative profiles on two-thirds of these flights. For measurements made in clear sky, agreement between the *in situ* profiles and remotely sensed profiles is excellent. Profiles were obtained in the presence of cirrus, but the MOPITT team has not yet produced retrievals for this condition. These *in situ* profiles will provide essential information once the retrieval issues have been dealt with satisfactorily. One problem with the flight-of-opportunity approach to validation is that no effort was made to obtain profiles for a range of atmospheric conditions. Luck did not provide a range, and the actual measurements vary by only about 10%. This experience underscores the need for the Aura investigators to specify the types of measurements that are required for successful validation.

Jim Anderson led a discussion on the Union of Missions, a document that develops the conceptual framework for improved collaboration between the airborne missions with each other and with spaceborne platforms including Aura. Jim talked about the missing components of the document and the progress being made. The importance of developing this conceptual framework was underscored during discussions of the proposed Tropical Composition, Cloud, and Climate Coupling Experiment (TC^4) (see below for summaries of presentations given by Paul Wennburg and Ross Salawitch). There are multiple questions concerning processes in the tropics and subtropics that will be addressed by the two phases of this mission. The flights that are proposed will provide unique and useful information; however, common sense and analyses show that the information that can be obtained by aircraft is limited. The satellite data have the potential to provide both context for interpretation of aircraft observations and some quantitative information to understand the processes on the global scale (see summary of presentation by Dessler). This ongoing dialogue promotes the coordinated application of data from satellite and aircraft to complex science questions.

The A-Train

The scope of scientific applications for data from Aura and several other satellites will be broadened by launching Aura and three Earth System Science Pathfinder (ESSP) missions — CloudSay, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), and the Orbiting Carbon Observatory (OCO) — to fly in formation with Aqua, in orbit since May 4, 2002. Aura observations of cloud heights (OMI), aerosols (OMI, HIRDLS), H_2O and temperature profiles (MLS, TES), and cirrus clouds (MLS, HIRDLS) — along with observations from other A-Train participants — will form a much more comprehensive picture of clouds, aerosols, and water vapor than is possible using observations from any single platform. There are many challenges to using this data in concert. For example, the nadir footprints from the various instruments vary drastically. To foster creative thinking and to raise awareness of the complementary observations expected from other platforms, one session of the Aura science team meeting featured presentations about the A-Train and the instruments that comprise it. **Chip Trepte** presented an overview of CALIPSO, which will provide observations of the vertical distribution and extinction for clouds and aerosols, emissivity of clouds, and single-scattering albedo for aerosols. **Charles Miller** described the measurements of CO_2 expected from OCO. **Mark Schoeberl** presented an overview of the A-Train and reviewed some of the measurement capabilities of its component missions. These include infrared cloud properties, temperature, and water from instruments on Aqua; vertical distribution of clouds by CloudSat; and measurements of aerosol and cloud polarization from a French Centre National d'Etudes Spatiales (CNES) mission called Polariazation and Anisotropy of Reflectances for Atomspheric Science copuled with observations from a lidar (PARASOL), which will also be part of the formation. It will also be possible to combine data from multiple missions to produce such quantities as observation-based assessments of the radiative effects of aerosol and clouds that will greatly improve our ability to predict future climate change.

Science Presentations

Presentations on topics of interest to the Aura community were solicited for this science team meeting and are summarized below.

Laura Pan presented an overview of the National Center for Atmospheric Research (NCAR) Upper Troposphere Lower Stratosphere Initiative. This initiative will bring together a critical mass of collaborators in a focused program of observations and analysis. Measurements that are part of this initiative during 2005 may be useful for validation of Aura data; and, once validated, Aura data will play a role in this initiative.

Paul Wennberg spoke of two closely related campaigns, the Tropical Composition and Climate Coupling (TC^3) Experiment and the Tropical Western Pacific component of CRYSTAL (CRYSTAL-TWP). Both TC^3 and CRYSTAL-TWP emphasize the processes that maintain observed humidity levels in the upper troposphere and lower stratosphere. This talk revealed a strategy for a mission TC^4 that combines the objective of TC^3 and CRYSTAL-TWP and also meets Aura validation requirements.

Ken Jucks provided an overview of the Far-Infrared Spectroscopy of the Troposphere (FIRST) instrument that is being developed to fly on a balloon payload. FIRST spectra can be inverted to yield profiles of upper tropospheric and lower stratospheric temperature and water vapor. Once validated, FIRST measurements can contribute to the validation measurements from HIRDLS and MLS on Aura and also AIRS, CERES, and MODIS measurements on Aqua and Terra.

Mark Kroon presented the OMI validation plan for aerosols and NO_2, emphasizing dedicated ground-based measurements. This project will provide a set of exclusive ground-based measurements, such as the NO_2 lidar data for polluted areas in the Netherlands, Multi-Axis Differential Optical Absorption Spectroscopy-Method (MAXDOAS) measurements of NO_2 in Paramaribo, and aerosol data. This data set will be used both to validate NO_2 and aerosol products and to improve the retrieval algorithms. It will also provide insight into the relationships between aerosol properties and NO_2 in polluted regions.

Dorian Abbot presented seven years (1995-2001) of HCHO column data for North America from the Global Ozone Monitoring Experiment (GOME), and showed that the general seasonal and interannual variability of these data is consistent with that produced using the GEOS-CHEM 3D tropospheric chemistry and transport model, and isoprene from current emission models. Regional discrepancies with the seasonal patterns predicted from these simulations may reflect flaws in the emission models.

Collette Heald presented results from the GEOS-CHEM 3-D tropospheric chemistry and transport model along with satellite observations of carbon monoxide (CO) from MOPITT and aircraft measurements from the TRACE-P aircraft mission. MOPITT observed four episodes of trans-Pacific transport of Asian pollution during spring 2001 that are simulated by the GEOS-CHEM model. The February 26-27 episode was sampled as a succession of pollution layers at 15-40º N by the TRACE-P aircraft over the northeast Pacific. The layers originate from the February 22 event of Asian outflow to the Pacific along a warm conveyor belt ahead of a cold front.

Joan Alexander showed examples of momentum flux estimates using measurements made by the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA). The temperature amplitude, vertical wavelength, and horizontal wavelength must be determined simultaneously to determine momentum flux and this has been a daunting analysis task for satellite observations. These results are relevant to HIRDLS observing strategies, particularly if the instrument performs as expected and it is possible to include an additional scan.

A presentation was given by **Ross Salawitch** on the combination of TC^3 and CRYSTAL-TWP complemented the talk given by Paul Wennburg, and emphasized the synergistic science that would result from the creation of TC^4. The importance of measurements of isotopes of water vapor (to study the processes which dehydrate air entering the stratosphere) and measurements of very short-lived organic species and their products (to determine the budget of chlorine- and bromine-containing species entering the stratosphere) was stressed.

Pepijn Veefkind showed trends in the aerosol optical thickness calculated from the global dataset derived from TOMS observations for 1979 to 2001. During this time period the emissions of aerosol precursors SO_2 and NO_2 have been drastically reduced. Because most of the aerosols over Europe are composed of sulfates and nitrates, it is expected that the reduction in emission will be manifest by a decrease in aerosol optical thickness and accompanied by regional warming.

Steve Massie discussed development of a cirrus cloud field that can be used in future tests of the HIRDLS retrieval algorithm. The cloud field is based upon 1994 observations from LITE (Lidar-in-Space Technology Experiment, a forerunner of CALIPSO), and extinction was normalized to values measured by the Halogen Occultation Experiment (HALOE) on the Upper Atmosphere Research Satellite (UARS). These studies clarify the expected performance for HIRDLS constituent retrievals in the presence of cirrus layers.

Hiroo Hayashi used observations from the Southern Hemispheric ADditional OZonesondes (SHADOZ) network to investigate tropical tropospheric ozone from the NASA GSFC ozone assimilation system. The shape of the annual mean vertical profile from assimilated ozone, produced using wind fields from a prototype version of the Goddard Earth Observing System Data Assimilation System (GEOS–4), compares better with observations than that produced using winds from a previous operational system (GEOS-2).

Andrew Dessler showed satellite and *in situ* evidence that the effects of convection on the Upper Troposphere / Lower Stratosphere (UT/LS) were dependent on the relative humidity of the UT/LS where the convection occurred. If convection injects mass into a region of high humidity, the convection can dehydrate that region, while convection into regions of low humidity hydrates that region. He also emphasized the importance of satellite data for the problem; the pervasive undersampling of aircraft data make those data virtually impossible to interpret on their own.

Laura Pan explored the utility of conceptual definitions of the extratropical tropopause as a material surface or as a mixing layer using fine scale *in situ* measurements of temperature, ozone, carbon monoxide, and water vapor. These analyses indicate that mixing of stratospheric and tropospheric air masses forms a transition layer in the vicinity of the thermal tropopause. The results also indicate that a Pressure-Volume (PV) based tropopause definition does not work well in locating the transition layer.

Mark Olsen used Lagrangian trajectories to show that a significant fraction of the air in the tropical upper troposphere/lower stratosphere during the wet/warm phase of the tape recorder originates from the extratropical Asian monsoon. Air reaches tropopause levels through convection within the monsoon and is transported equatorward. Data from Aura and Aqua instruments should clarify the relative contributions of air that have passed through the cold tropical tropopause and moist monsoon air to the observed tape recorder signal.

Pepijn Veefkind presented different aspects of a new algorithm to improve the total ozone product from the GOME instrument by combining the GOME experience with the new insight gained from development of OMI algorithms. The proposed algorithm includes an accurate method to derive and use the cloud fraction and height, a tool that recalibrates the GOME Level 1 data and the main features of the OMI Differential Optical Absorption Spectroscopy (DOAS) total ozone algorithm.

Ivanka Stajner showed how the ozone data assimilation system at NASA's Data Assimilation Office (DAO) is preparing for Aura with a series of experiments investigating the use of column ozone from either the Total Ozone Mapping Spectrometer (TOMS) or the Solar Backscatter UltraViolet (SBUV) instrument, and vertical ozone profiles from SBUV. Assimilation of additional data, improved forecast error covariance models, and incorporation of chemistry models each lead to incremental improvements in the assimilated ozone fields.

Krzysztof Wargan demonstrated the impact of changing the forecast error covariance model from a version assuming static correlations to a flow-following scheme that captures the Lagrangian short-term horizontal evolution of those correlations. The ozone fields produced from the assimilation system using the flow-following covariance compares better with independent observations within the regions where data were not assimilated, particularly at high latitudes in both hemispheres.

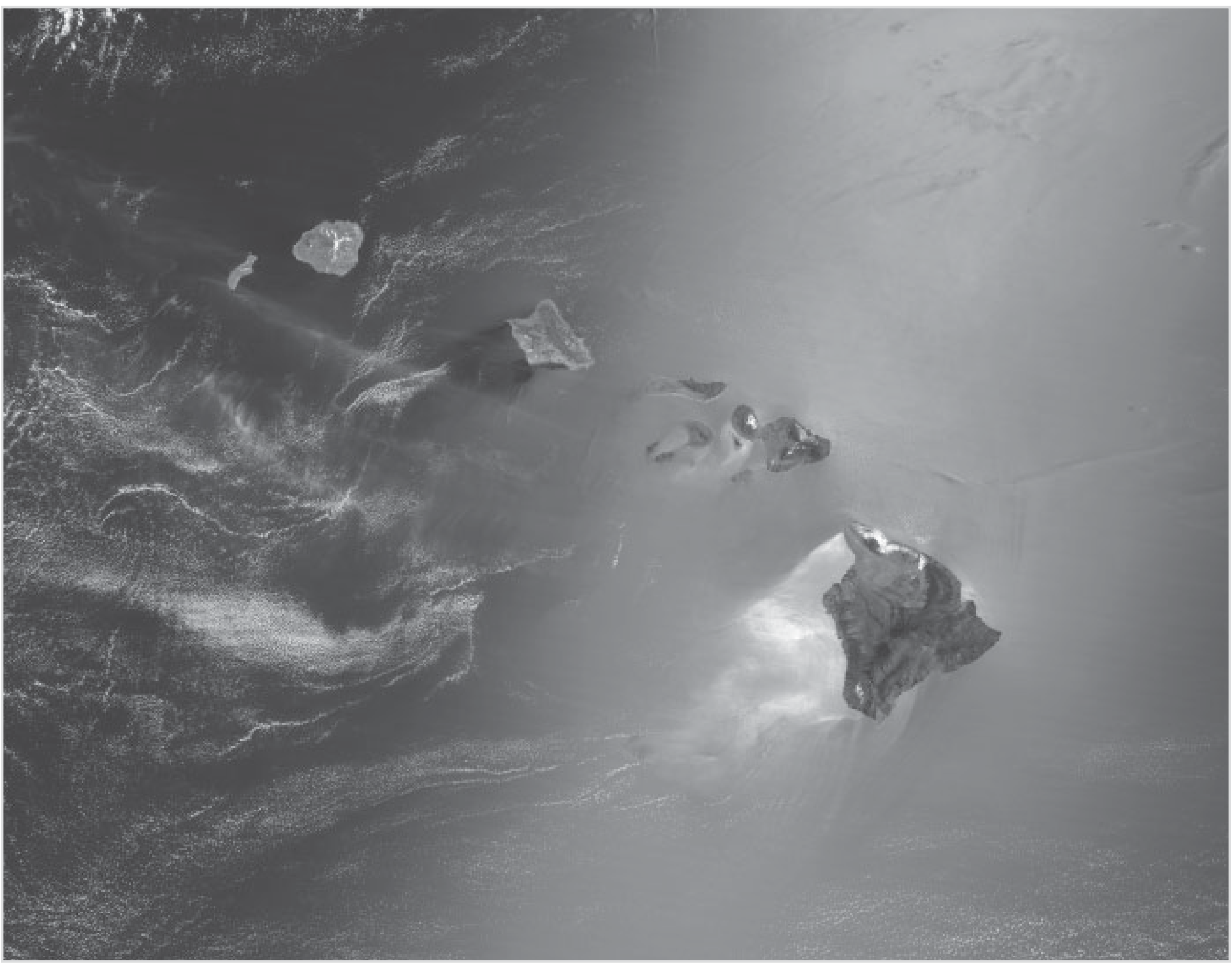
David Lary used an assimilation scheme including a photochemical model constrained by multiple coincident observations to reconstruct full diurnal cycles from limited observations and to check their chemical self-consistency. This approach propagates sunrise and sunset information obtained through solar occultation for validation of measurements made at other times of day.

Gloria Manney showed process-based diagnostics for meteorological fields from a number of data assimilation systems, including versions 3 and 4 of the Goddard Earth Observing System Data Assimilation System (GEOS DAS), the European Centre for Medium-Range Weather Forecasting (ECMWF), the MetO (formerly known as UKMO), NCEP, and the NCEP reanalysis. Modeling studies, particularly those involving transport or temperature-dependent threshold phenomena, can be highly sensitive to the choice of meteorological analysis used.

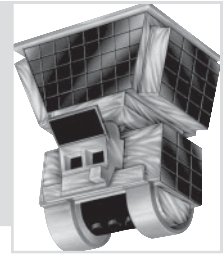
A few posters were displayed throughout the meeting. **Nathan Winslow** presented a poster detailing improvements in the NASA GSFC ozone assimilation product relative to ozone sondes when MLS profiles are assimilated along with TOMS columns and SBUV profiles. A poster by **Alexander Sinyuk** presented a method for retrieval of the imaginary part of the refractive index of desert dust aerosol at near-UV wavelengths. **Omar Torres** showed comparisons of the aerosol optical depth and single-scattering albedo derived from near-UV observations by the Earth Probe Total Ozone Mapping Spectrometer with observations made at AERONET stations in Africa and in the United States. TOMS and AERONET single-scattering albedo agree within 0.03. **Mark Schoeberl** used diabatic heating rates to calculate the flux of mass from the stratosphere to the troposphere, and attributed the mass change in the lowermost stratosphere to diabatic and adiabatic processes. Results were found to differ depending on the source of meteorological fields used in the analysis. He also found that there was a net adiabatic flux of mass into the middle world.

The next Aura Science Team meeting will be held in Pasadena, CA, the week of September 30, 2003. This meeting will include a field trip to visit the Aura spacecraft before its January 2004 launch.

A silver swath of sunglint surrounds half of the Hawaiian islands in this true-color Terra MODIS image acquired on May 27, 2003. Sunglint reveals turbulence in the surface waters of the Pacific Ocean. If the surface of the water were as smooth as a mirror, we would see the circle of the Sun as a perfect reflection. But because the surface of the water is ruffled with waves, each wave acts like a mirror and the Sun's reflection gets softened into a broader silver swath, called the sunglint region. Image courtesy Jacques Descloitres, MODIS Land Rapid Response Team at NASA GSFC.



CERES Science Team Meeting



— Gary G. Gibson, Gary.G.Gibson@nasa.gov, NASA Langley Research Center
— Shashi K. Gupta, s.k.gupta@larc.nasa.gov, NASA Langley Research Center

The 28th Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held in Norfolk, VA, on May 6-8, 2003. The meeting focused on the new Monthly Top-of-Atmosphere/Surface Averages (SRBAVG) products, early results from Terra Angular Distribution Model (ADM) development, cloud accuracy results from Terra, Terra Edition2 instrument and ERBE-like (ERBE is the Earth Radiation Budget Experiment) results with calibration refinement, Aqua Instrument and ERBE-like product status, and performance of Terra surface fluxes. The next CERES Science Team Meeting is planned for September 23-25, 2003 in, Hampton, VA.

CERES on NPOESS and NPP

Bruce Wielicki (Langley Research Center [LaRC]) noted that a clear picture of CERES on the National Polar Orbiting Environmental Satellite System (NPOESS) is not expected to emerge until next year. The Earth Science Enterprise has directed that provisions be made to accommodate a CERES instrument on the NPOESS Preparatory Project (NPP) spacecraft to fill the anticipated gap in the radiation budget data record between Aqua and NPOESS. This leaves the door open to fly CERES on NPP, but a final decision has not been made. Aqua and Terra will not be de-orbited; the latest estimate of risk of a gap in broadband radiation budget data without CERES on NPP is 16 to 42% through 2012, depending on Geostationary Earth Radiation Budget (GERB) success, launch dates, and mission lifetimes. CERES on NPP reduces the gap risk to 6%.

CERES Instruments on Terra and Aqua

Kory Priestley (LaRC) gave the instrument calibration/validation report. The Terra Deep Space Calibration sequence executed flawlessly and science data analysis is continuing. Initial results indicate minimal changes from pre-launch measurements of scan angle dependent offsets. Terra Edition2 bi-directional scan (BDS) and ERBE-like products are available through December 2002. A factor of five improvement has been achieved in stability and bias for shortwave (SW) and daytime longwave (LW) Edition2 products. Terra has unprecedented stability levels of ~0.1%/yr for the CERES climate record. Aqua Edition1 BDS products are now available. Intercalibrations between Terra and Aqua allow the instruments to be placed on the same radiometric scale: The SW and LW/night agreement is within 0.4%; LW/day agreement is better than 0.7%; and window channel (WN) agreement is within 1.0%.

Terra Edition2 ERBE-Like Flux

Takmeng Wong (LaRC) examined the time series of CERES/Terra Edition2 tropical-mean and global-mean top-of-atmosphere (TOA) radiation budgets and found no statistically significant trends during the first 34 months of data. His analyses also revealed that regional radiative effects of the 2002 El Niño event are large, up to 80 W/m^{-2}. A comparison of ERBE-like and SRBAVG results for March 2000 showed a large clear-sky bias away from the Tropics, small LW differences in most zones, and a large latitudinal dependence in all-sky SW and net flux biases.

TRMM and Terra Time-Averaged Products

David Young (LaRC) reported that the Terra gridded geostationary (GGEO) products are now being run for the first year of data. Improvements related to surface emissivity, sun angle, and time-dependent calibrations were incorporated. Other enhancements involving geostationary satellite navigation, surface albedo, and bringing in new satellites are in progress. Validation is continuing for the archived Tropical Rainfall Measuring Mission (TRMM) SRBAVG product. A beta version of the Terra SRBAVG marks the first of a new generation of global monthly mean products. The Terra beta Monthly Gridded TOA/Surface Fluxes and Clouds (SFC) product is in the archive, and the Aqua beta SFC product has been delivered.

TRMM/Terra Clouds and Radiative Swath (CRS) Results

Tom Charlock (LaRC) reported that TRMM CRS Edition2C was produced, but still neglects organic carbon aerosols and has a few other known errors. The LaRC Fu-Liou radiative transfer code is being modified to: 1) produce multiple-sky condition outputs including clear-sky with and without aerosol, and all-sky with and without aerosol for multiple-cloud conditions; and 2) include a new inhomogeneous cloud optical depth solver. Code structural modifications have been introduced which reduce execution time for Surface and Atmosphere Radiation Budget (SARB) by about 40%.

Angular Distribution Models

Norman Loeb (Hampton University) presented results of TOA radiative-flux estimation from CERES ADMs. Early results from Terra ADMs show improvement over those from TRMM, especially outside the Tropics. Final Terra ADMs based on 2 years of CERES/Terra rotating azimuth plane (RAP) measurements will be completed in September 2003. More work is needed to evaluate the quality of 1°-resolution SW clear land ADMs and fits for ocean LW ADMs. SW and LW ADMs are not yet developed for clouds over land and desert. Part I of a journal paper describing CERES/TRMM SW, LW, and WN ADMs was published, and Part II summarizing TRMM ADM validation results was accepted. Another paper on the use of neural networks for TOA flux estimation was also accepted.

Cloud Algorithms and Results

Patrick Minnis (LaRC) summarized cloud system results and validation for Terra, and algorithm improvements and initial results for Aqua, and required algorithm enhancements for handling multi-layer clouds, polar clouds, and partly-cloudy pixels. TRMM Visible-InfraRed Scanner (VIRS) Edition2 processing is complete, Terra Edition1a has been run for February 2000 to January 2002, and Aqua Beta1 is now available for September and October 2002. Overall, validation results are encouraging and a roadmap for improving known deficiencies is in place.

Data Management

Mike Little (LaRC) reported on the status of science data products, processing environment, and technology advances. TRMM data processing is complete until the next major reprocessing. Terra Edition2 is complete through the end of 2002. A combined Terra/Aqua Edition1 product is planned. Several hardware changes are underway to improve the environment for development and testing of science codes and provide computing capacity for unscheduled requirements. In the longer term, software may be converted to operate in an open source (LINUX) environment to improve efficiency. **James Koziana** (SAIC) briefed the team on ordering data from the Atmospheric Sciences Data Center (ASDC) and on subsetting CERES data products. **Michelle Ferebee** (LaRC) reported on the status of the ERBE Digital Library being developed at the ASDC.

Educational Outreach

Lin Chambers (LaRC) reported that the CERES Students' Cloud Observations On-Line (S'COOL) project now has 1450 participating schools in 62 countries. The 5th annual S'COOL teacher workshop will be held in June. The latest S'COOL newsletter was distributed in March in English, French, and Spanish.

Invited Presentations

Grant Matthews (Imperial College, London) presented the status of the GERB instrument which was launched in August 2002 aboard the Meteosat Second Generation (MSG) satellite. The GERB experiment is a cooperative project between U.K., Belgian, and Italian scientific institutions and was built and calibrated in the U.K. It is the first instrument to measure the broadband SW and LW radiation budget from a geostationary platform. GERB produces a radiation budget map every 15 minutes at a spatial resolution of 40 km x 40 km which will be enhanced to 10 km x 10 km using data from Spin Enhanced Visible InfraRed Imager (SEVIRI), a high spatial resolution imaging instrument also flying aboard the MSG. GERB processing is using many of the data reduction procedures developed for CERES. Design lifetime of a GERB instrument is 3-5 years.

Takmeng Wong (LaRC) and **Zachary Eitzen** (Colorado State University) presented results from a study of cloud systems motivated by the desire to better understand cloud-radiative feedbacks in the climate system and reduce uncertainties in the simulation of cloud-radiation interactions in the global climate models (GCMs). This study involved analysis of the subgrid-scale characteristics of clouds obtained from the CERES cloud processing system and comparing them with results of simulations from models driven by meteorological input data from the European Centre for Medium-Range Weather Forecasts (ECMWF). CERES/TRMM cloud retrievals for March 1998 (strong El Niño) and March 2000 (weak La Niña) were analyzed. Probability density functions and other statistics were derived for TOA SW flux, outgoing LW, TOA albedo, cloud optical depth, liquid water path (LWP), ice water path (IWP), and other cloud parameters. Cloud-height distributions for tropical deep convective systems were found to be very different for El Niño and La Niña conditions. Cloud top height and LW distributions were found to be insensitive to sea surface temperature changes above 301 K.

Xiquan Dong (University of North Dakota) presented validation of cloud properties derived by the LaRC cloud group from Terra Moderate Resolution Imaging Spectroradiometer (MODIS) data against ground-based measurements from the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) and North Slope of Alaska (NSA) sites. Comparisons at the SGP site were presented for the period from November 2000 to December 2001. Two methods were used for averaging satellite retrievals. For the first method, data were averaged over a 30-km x 30-km area centered on the site. For the second method, data were averaged along a 3-km wide wind strip over one hour centered on the time of satellite overpass. Wind speed and direction were obtained from the ECMWF data. Dong found that the wind strip method was more successful at detecting clouds. Cloud heights showed good agreement for solid cirrus and mid-level clouds. For stratus clouds, wind strip average values of particle size agreed well with surface data, but optical depth and LWP values were much lower.

Investigator Presentation Highlights

David Kratz (LaRC) presented validation of Terra Single Scanner Footprint (SSF) surface-only SW and LW fluxes derived using TOA-to-surface transfer algorithms and fast radiation parameterizations. Validation was done on an instantaneous/footprint basis using surface-measured fluxes from a number of different climate regimes. Kratz concluded that clear-sky and all-sky LW fluxes meet the stated accuracy goal of ±20 Wm^{-2} considered desirable for climate research applications. Clear-sky SW fluxes showed good agreement, but all-sky fluxes showed a large scatter caused by cloud spatial variability. Efforts are underway to improve the all-sky SW comparisons.

Gerald (Jay) Mace (University of Utah) presented results from a case study of the evolution of a cirrus anvil based on satellite, aircraft, and surface-based observations on July 16, 2002, during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE). Geostationary Operational Environmental Satellite (GOES) data provided the temporal context while aircraft and surface data provided vertical cross sections. Mace concluded that combined observations like these should be used to derive cloud properties and to examine the statistics of the empirical relationships for different cloud types and events.

James Coakley (Oregon State University) presented results of a new method for retrieving cloud properties from partially cloud-filled pixels. He stated that partially cloud-filled pixels occur even at the highest spatial resolution (including 1-km MODIS data). Cloud properties derived from these pixels with a clear/overcast threshold method are subject to significant errors. The partially cloudy method is based on adjusting the cloud amount, optical depth, and droplet radius to ensure a match between computed and observed radiances at 0.64, 3.7, and 11 µm. Coakley's results for several scenes of VIRS 2-km data and MODIS 1-km data showed that a threshold method generally overestimated the cloud cover, underestimated the optical depth, and overestimated the droplet radius.

Bing Lin (LaRC) presented results from a study of liquid/ice water paths and the vertical structure of clouds as observed from instruments aboard the TRMM satellite by comparing cloud properties retrieved from VIRS and TRMM Microwave Imager (TMI) data. VIRS-based retrievals came from CERES processing; Lin's microwave radiative transfer model was used to analyze the TMI data. For comparison, VIRS cloud products were convoluted to match the larger TMI fields-of-view. CERES/VIRS and TMI LWP retrievals for warm clouds were found to be in very good agreement. VIRS overestimation of IWP for high clouds was attributed to the presence of low clouds underneath the cirrus layers.

Robert Cess (State University of New York, Stony Brook) analyzed the impact of clouds on the radiation budgets of 19 atmospheric GCMs. He expressed concern that a dozen years ago the estimated temperature response to CO_2 doubling among the models varied by a factor of 3, and the situation has not changed much since then. He compared the effects of clouds in 19 GCMs against results from multi-year 3-month averages of SW, LW, and net cloud radiative forcing (CRF) from ERBE observations. For zonal averages, most models underestimated SW CRF while LW CRF compared better. Averages of net CRF over a 60N-60S domain agreed well for some models but not for others. Comparisons of net CRF over the Pacific Ocean showed that some models compared better over the eastern region while others did better over the western region. Comparisons of clear-sky reflected SW flux and outgoing LW showed disturbingly large differences between the models and relative to ERBE values.

Anand Inamdar (Scripps Institution of Oceanography) presented a study of the atmospheric LW cooling over tropical oceans inferred from CERES/TRMM data. He analyzed TRMM/SSF data to demonstrate the magnitudes of LW cooling separately for the WN and non-window regions. Specifically, imager-based surface skin temperature, microwave precipitable water vapor over oceans, outgoing LW, outgoing WN flux, and downward broadband and WN fluxes were analyzed. Corresponding non-window quantities were computed from the broadband and WN values. Inamdar presented plots of WN and non-window surface and atmospheric cooling effects as functions of sea surface temperature and column precipitable water vapor.

Shi-Keng Yang (NOAA National Centers for Environmental Prediction, NCEP) presented an analysis of the trends in tropospheric humidity in the NCEP/National Center for Atmospheric Research (NCAR) reanalysis during the pre-satellite period (1949-1978). He showed that TOA LW CRF in the reanalysis continually decreased during this period and was related to the decrease in 500 hPa relative humidity. Yang also analyzed TOA and surface radiative fluxes from the latest Atmospheric Model Intercomparison Project (AMIP) simulations at NCEP, that used the current global forecast model. He concluded that the current NCEP global forecast model was not able to simulate the ERBE and CERES observations well. Like many other GCMs, it did not reproduce the decadal variability of TOA radiation shown by Wielicki et al. from satellite observations.

Ron Welch (University of Alabama in Huntsville/UAH) presented comparisons of CERES- and MODIS-derived cloud masks over the ARM/NSA site with various ground-based measurements. Large differences were found between CERES mask and surface estimates, particularly for high, thin clouds. The MODIS algorithm generally detected more high, thin clouds than the CERES algorithm but sometimes found clouds where surface data indicated clear skies.

Qingyuan Han (UAH) identified two important sources of uncertainty in the retrieval of ice cloud properties. The first is the use of empirical particle size distributions. He suggested that the use of theoretical size distributions greatly reduces the large uncertainties in single scattering properties. The second source of uncertainty was the use of a single crystal habit (shape) by many retrieval algorithms. For example, the CERES algorithm assumes ice particles to be hexagonal columns, ISCCP algorithm assumes them to be polycrystal, and MODIS algorithm assumes a combination of three shapes. These assumptions lead to large uncertainties in effective particle size, single scattering properties, as well as cloud emissivity and albedo. Han suggested that more realistic habits could be derived using CERES RAP observations.

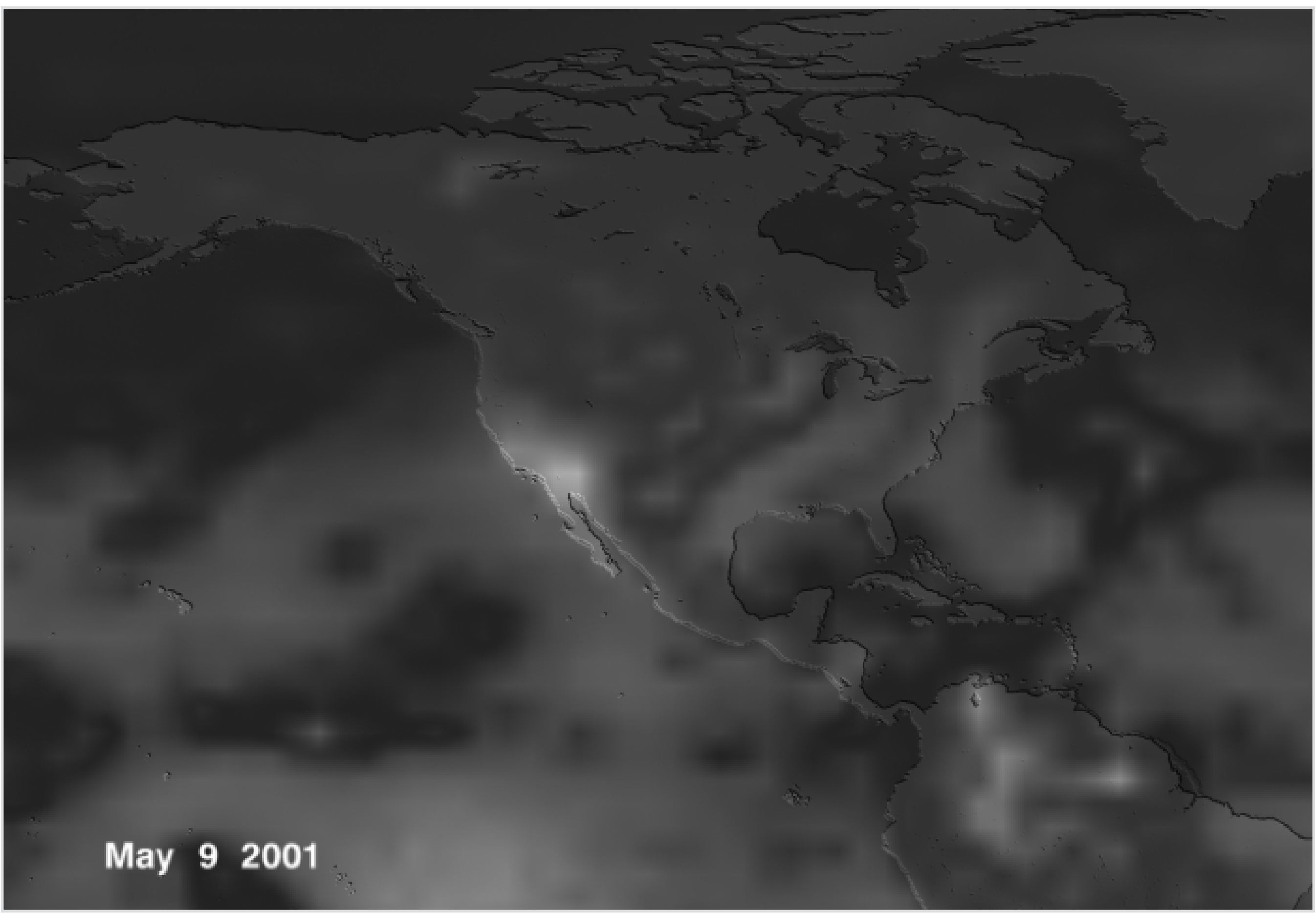
Michel Viollier (Laboratoire de Meteorologie Dynamique, France) compared CERES/Terra and early GERB measurements with broadband fluxes derived from POLarization and Directionality of Earth's Reflectances (POLDER) data by using narrowband-to-broadband conversion algorithms. POLDER-2 began providing data in early February 2003 and became fully operational in April. Viollier also discussed the status of Megha-Tropiques, a cooperative Indo-French mission which will carry two passive microwave instruments and a radiation budget instrument in a low-inclination orbit for studying tropical water and energy cycles.

Nicolas Clerbaux (Royal Meteorological Institute of Belgium, RMIB) reported on the status of activities at the RMIB where high spatial and temporal resolution TOA radiative fluxes will be produced using observations from a geostationary platform. This will be accomplished with a coordinated use of data acquired by the GERB and SEVIRI instruments aboard the MSG satellite. A resolution enhancement technique will be used to connect the broadband GERB flux retrievals to 10 km x 10 km blocks of SEVIRI pixels.

Thomas Charlock (LaRC) presented an assessment of the direct aerosol forcing (DAF) of TOA, surface, and atmospheric radiative fluxes for clear- and all-sky conditions. Clear-sky results were presented for a month (April 1998) and all-sky results for a day (June 17, 1998). He found good agreement for April 1998 between DAF values at the TOA for tuned clear-sky fluxes and for CERES observations. Charlock used Global Aerosol Climatology Project data to show the distribution of aerosol optical thickness (AOT) differences between April 1998 and April 1989 to contrast an El Niño year (1998) with a non-El Niño the Southern Hemisphere (SH) and lower AOT in the Northern Hemisphere (NH) during April 1998, and suggested that the El Niño may be causing a decrease (increase) of AOT over the NH (SH) oceans. Also, since most of the aerosol heating of the atmosphere occurs in the NH, the April 1998 El Niño may be suppressing that atmospheric heating.

Alexander Ignatov (NOAA National Environmental Satellite, Data, and Information Service, NESDIS) compared aerosol optical properties retrieved over the oceans as a part of CERES processing with corresponding MODIS retrievals. CERES retrievals were made with single channel (like the Advanced Very High Resolution Radiometer, AVHRR) algorithms while MODIS retrievals were made with a multi-channel algorithm. Several comparisons of both Terra and Aqua retrievals for AOT at 0.659 and 1.64 μm, and the Angstrom exponent, Å, were shown. The two products showed good agreement.

T. Zhao (NOAA/NESDIS) examined the differences of AOT and Å, retrieved with AVHRR-like and MODIS algorithms, and also compared them with Aerosol Robotic Network (AERONET) observations for March 2001. He found that the differences of AOT at both wavelengths (0.659 and 1.64 μm) were caused primarily by cloud contamination of the clear footprints used in retrievals. Reducing the effects of cloud contamination on the retrievals brought the results of the two algorithms close to each other and to the AERONET observations.



CERES measured the thermal energy or heat emitted from the United States, as shown in this image from May 2001. The record-setting high temperatures experienced in Southern California and Nevada on May 9 are visible in the light areas where great amounts of thermal energy are escaping to space. This example illustrates one of the most basic stabilizing forces in the Earth's climate system: clear hot regions lose more energy to space than cold areas. The regions of low thermal emission over the northern U.S. are cold cloud tops. CERES data will be used to verify the ability of climate models to accurately predict this emission as our world experiences changes in surface reflectivity, clouds, atmospheric temperatures, and key greenhouse gases such as water vapor.

Summary of the Joint CloudSat/CALIPSO Science Team Meeting

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A joint CloudSat/Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Science Team meeting was held March 3-6, 2003, in Broomfield, CO, and was chaired by the respective Principal Investigators (PIs), Graeme Stephens (Colorado State University) and Dave Winker (NASA-Langley Research Center). The CALIPSO and CloudSat satellites are co-manifested on a Delta II, scheduled for launch in November 2004. Many of the science team members belong to both missions, and much of the science return and many of the scientific operations are of interest to both groups. The meeting was well attended and participant feedback indicates the meeting was very successful. Another joint Science Team meeting will be planned as the missions near launch.

Afternoon Constellation ('A-Train')

CALIPSO and CloudSat are NASA Earth System Science Pathfinder (ESSP) missions and will become part of the Afternoon Constellation (known informally as the "A-Train" after the famous jazz tune "Take the A-Train," by Billy Strayhorn—See NASA Facts, FS-2003-1-053-GSFC for additional information). The other satellites in the polar-orbiting constellation are Aqua, Aura, and Polarization and Anisotropy of Reflectances for Atmospheric Science Coupled with Observations from a Lidar (PARASOL), a French Centre National d'Etudes Spatiales (CNES) mission. The five satellites mentioned above will eventually be joined by a sixth, the ESSP-sponsored Orbiting Carbon Observatory (OCO).

CloudSat Mission

CloudSat will carry a special type of high frequency radar (94 GHz). This cloud-profiling radar (CPR) will provide the vertical distribution of cloud physical properties including liquid water content, ice content, and cloud optical depth [Stephens et al., 2002]. The CloudSat mission is a cooperative effort that includes its international partner, Canada, and its industry partner, Ball Aerospace and Technologies Corporation. Among CloudSat's other partners are Colorado State University (CSU), Jet Propulsion Laboratory (JPL), Canadian Space Agency, the U.S. Air Force, U.S. Department of Energy, Goddard Space Flight Center and scientists from France, United Kingdom, Germany, Japan and Canada. For additional information, the CloudSat website is: cloudsat.atmos.colostate.edu/.

CALIPSO Mission

CALIPSO will carry a two-wavelength, polarization lidar and two passive instruments to provide an opportunity for more comprehensive atmospheric data collection on aerosols and optically thin cirrus. Lidar is similar to radar but sends pulses of light generated by a laser through the atmosphere,

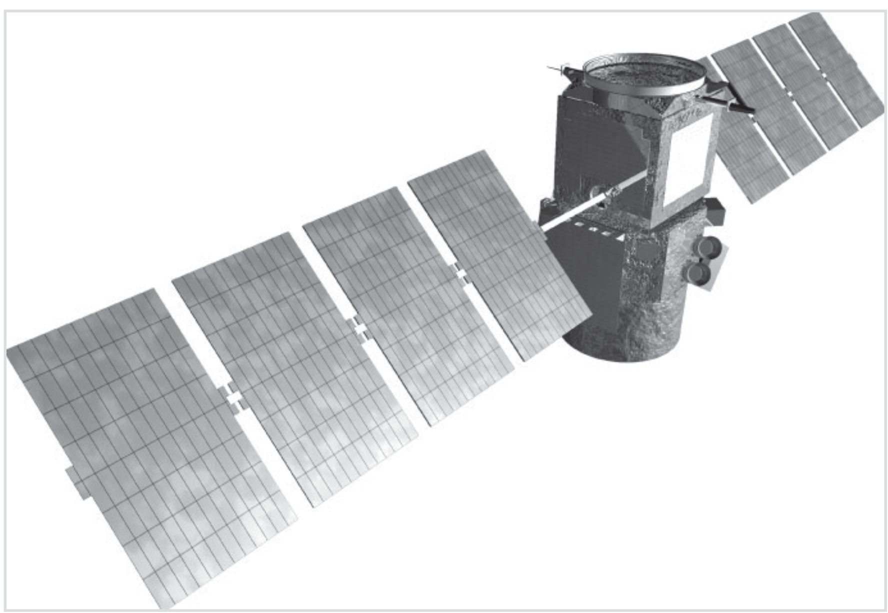

Figure 1: The Cloud Aerosol Lidar and Infrared Pathfinder Sallite Observations (CALIPSO) Satellite

where a fraction is then scattered by aerosols and cloud particles back to the instrument . The CALIPSO satellite will provide vertical profiles of aerosols and clouds using the first satellite lidar dedicated to atmospheric sensing [Winker et al., 2003]. The lidar will observe the vertical distribution of aerosols and clouds and the passive instruments will provide additional information on particle properties, improving our understanding of the role aerosols play in Earth's climate system. The CALIPSO mission is a cooperative effort led by NASA's Langley Research Center (LaRC) and includes the French space agency CNES, Hampton University, Ball Aerospace and Technologies Corporation (Ball), and the French Institut Pierre Simon Laplace. For additional information, the CALIPSO website is: *www-calipso.larc.nasa.gov*.

Joint CloudSat/CALIPSO Science Team Meeting

Monday, March 3

The first day of the meeting was a focused CALIPSO Science Team session, which included presentations on recent characterization test results for the lidar detector and the status of Level 2 lidar algorithms. This session was adjourned for a tour of CALIPSO and CloudSat hardware at the nearby Ball facility in Boulder. The meeting reconvened that evening with a joint CloudSat/CALIPSO town hall session to discuss strategy for a NASA Research Announcement (NRA) as well as concepts for the next mission. The Mission PIs, Graeme Stephens (CSU) and Dave Winker (LaRC), and Earth Science Enterprise (ESE) Program Manager for Radiation Science, Don Anderson (NASA Headquarters—Code YS) led the discussion.

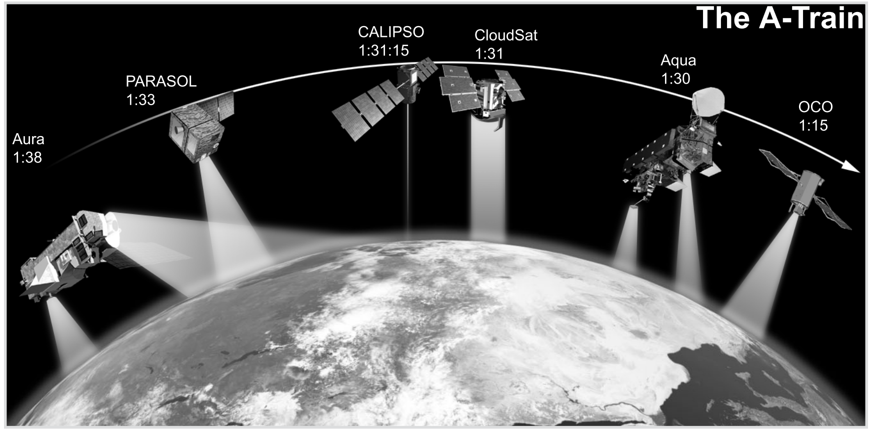

Figure 2: The A-Train satellite constellation.

Tuesday, March 4

Tuesday morning kicked off three days of joint CloudSat/CALIPSO sessions with a welcome from the Mission PIs and opening remarks from Don Anderson. Tuesday's joint session included project status reports by CALIPSO and CloudSat project management. John Rogers (LaRC), the CALIPSO Project Manager, highlighted the recently approved project replan. Mark LaPole (Ball), the CALIPSO Payload Manager presented the status of the payload, highlighting progress in each of the payload components. Tom Livermore (JPL), the CloudSat Project Manager, gave an overview of project status and Randy Coffey (Ball), the CloudSat Spacecraft Manager, presented an overview of the spacecraft, highlighting recent progress in development. John Stadler (LaRC), the CALIPSO Systems Engineer, discussed changes to the on-orbit formation to minimize impacts of sun glint on the overall science objectives. The rest of the morning and afternoon were dedicated to updates of the science algorithms and descriptions of data products (Joint Session III). A reception held Tuesday night at the Omni was the site of the now infamous CloudSat Cup Competition. Because of the number of injuries during previous competitions, checkers was chosen as the 'sport event.' Traditionally, the CloudSat Cup pits the engineers against the scientists and traditionally, the scientists led by Graeme Stephens have won. Congratulations to the engineers, led by Tom Livermore, who emerged victorious for the first time in four years—unfortunately the coveted CloudSat cup disappeared during the evening.

Wednesday, March 5

Wednesday morning, Joint Session IV, addressed the progress in global climate modeling and data assimilation and took advantage of the local expertise at NCAR and CSU, as well as the international mission participation from CloudSat and CALIPSO. This theme continued during the afternoon in Joint Session V that consisted of special reports on other missions. Didier Tanre (Laboratoire d'Optique Atmospherique/Centre National de la Recherche Scientifique), PI on PARASOL, brought everyone up to date on PARASOL and its instrument, Polarization and Directionality of Earth Reflectances (POLDER 2). Pedro Baptista (ESA/ESTEC) discussed EarthCare simulation, and Francisco Valero (Scripps Institution of Oceanography/UCSD) gave an overview of

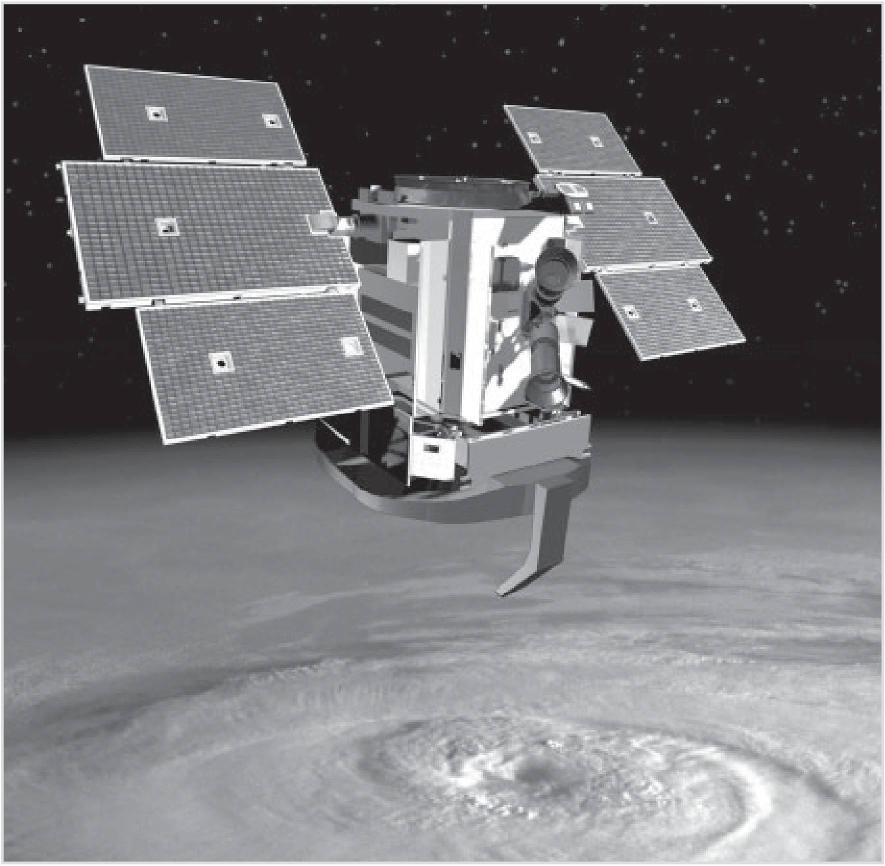

Figure 3: The CloudSat Satellite

Deep Space Climate Observatory (DSCOVR—formerly Triana). Validation is a topic of extreme importance to any mission, and the Validation Activities session was the focus for the remainder of this meeting. Among the current and future campaigns and field experiments that were discussed and offer potential benefit to CloudSat and CALIPSO were the Cirrus Regional Study of Tropical Anvils and Cirrus Layers Florida Area Cirrus Experiment (CRYSTAL-FACE), the Tropical Western Pacific Campaign, the Atmospheric Radiation Measurement Program (ARM), MIRAI, Regional East Atmospheric Lidar Mesonet (REALM), and others. The validation activities of other satellite missions including Aura (another A-Train member) and Terra were also presented.

Thursday, March 6

The final day of the meeting began with CALIPSO taking credit for the CloudSat "cupnapping." A ransom note was delivered shortly after the meeting and it is believed that the CloudSat Cup is currently on a worldwide tour until those demands are met. The morning presentations began with a break from validation. The CALIPSO Co-PI, Pat McCormick (Hampton University), teamed with Debra Krumm (CSU), director of education and public outreach for CloudSat, to describe the cooperative plans that the two missions have for reaching out to the public and to students around the world in Joint Session VII. Students will be organized to collect data to provide ground-based observations through the NASA-sponsored Global Learning and Observations to Benefit the Environment (GLOBE) program.

The final day returned to the validation theme with several more presentations, and the meeting concluded with a session on one of the groundbreaking aspects of these two missions, combining multi-sensor data (Joint Session VIII). Combining sensors achieves synergy, meaning more information about the Earth will be obtained from the combined observations of the different satellites and their instruments as a formation, than would be possible from the sum of the observations taken independently. Achieving synergy between the missions will also be one of the most difficult engineering aspects of the two missions and the remaining presentations highlighted the promise and potential of these synergistic observations.

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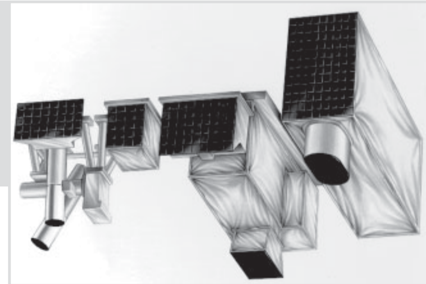
ASTER Users Workshop

— *Mike Abrams, Michael.J.Abrams@jpl.nasa.gov, Jet Propulsion Laboratory*



The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Users Workshop was held April 28-29, 2003, in Arcadia, California near the Jet Propulsion Laboratory (JPL). Over 100 participants attended the two-day workshop dedicated to teaching users about ASTER data. The first day of the workshop was devoted to descriptions of the instrument, calibration, data products, and data ordering tools. The second day was devoted to presentations of scientific applications. Speakers came from the U.S. ASTER Science Team, the Land Processes Distributed Active Archive Center (LPDAAC), the Japanese Ground Data System, and the University of California Davis. Throughout the two days, participants had access to internet-enabled workstations. With the assistance of LPDAAC staff, they were able to learn how to search and order ASTER data through the U.S. and Japan data systems, explore the data through the Global Visualization (GLOVIS) tool, and order U.S. data through the Data Pool tool.

Michael Abrams, JPL, Associate ASTER Science Team Leader, welcomed the participants and presented the agenda for the two-day workshop. **Anne Kahle**, JPL, ASTER Science Team Leader, presented an overview of the ASTER instrument, the history of the ASTER project, and described the collaboration between the U.S. and Japan.

Radiometric calibration was covered by **Stuart Biggar** and **Kurt Thome** (University of Arizona) and **Simon Hook** (JPL). They described how calibration and validation of the ASTER instruments is done through analysis of on-board calibration lamps and their response; and through regular, intensive field validation campaigns. Field work involves selecting large, homogeneous ground targets, such as dry lakes, sand dunes, and lakes. The sites are occupied during instrument overpasses, and thoroughly instrumented to measure surface radiative characteristics, solar radiance, meteorological conditions, etc. The measured surface parameters are convolved with models, and the values are compared to the instrument -measured values.

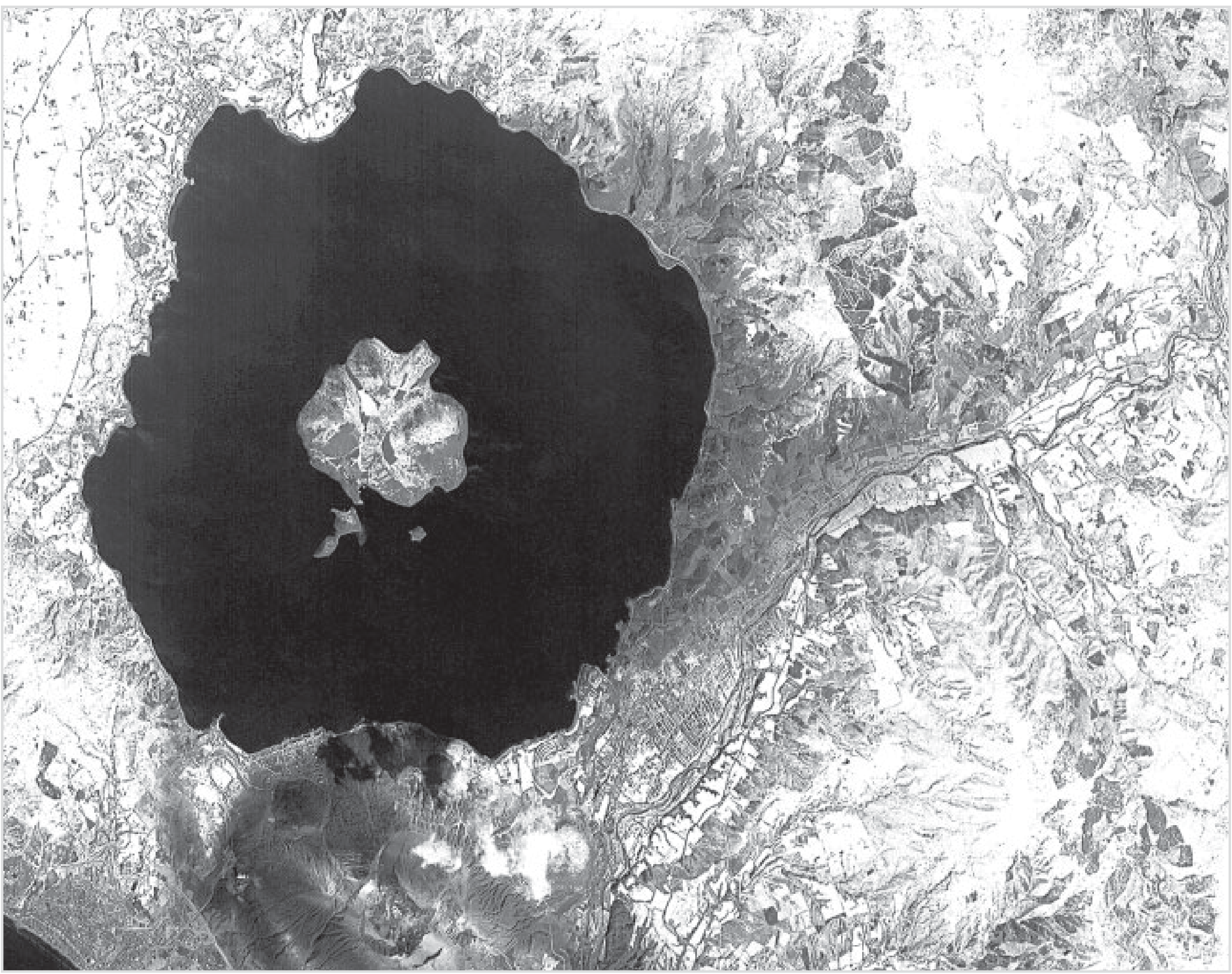
The next presentation was by **Michael Abrams**, covering the ASTER data products. ASTER provides 14 standard data products; some are geophysical, derived products, such as reflectance at the surface. Each product is periodically validated to verify performance of the algorithms, and to look for instrument anomalies.

The remainder of the afternoon was devoted to descriptions of data ordering and browsing tools available online. **Hiroshi Watanabe** discussed the Japanese Ground Data System and the browse and order capabilities offered through web sites. In addition, he described the scheduling and data processing done in Japan. **Bryan Bailey**, **Bhaskar Rhamachandran**, and **Zheng Zhang** from the Land Processes DAAC described the EOS Data Gateway web tool used in the U.S. to access all EOS data. They also described two ASTER-specific tools: the Global Visualization Viewer (GLOVIS), a tool for browsing images; and Data Pool, a tool to download data only over the US.

Larry Rowan (US Geological Survey [USGS]) opened the second day of applications discussions, and talked about using ASTER data for mineral mapping. He showed how to use shortwave infrared data with visible and thermal data to extract mineral spectral signatures, and described the limitations of the ASTER discrete bands. **Tom Schmugge**, U.S. Department of Agriculture, described his research into extracting surface energy-balance parameters by combining ASTER data, field measurements, and analytical models. **Simon Hook**, JPL, talked about lake studies using ASTER thermal data. His study site at Lake Tahoe illustrated using the data for temperature monitoring, and lake circulation studies. **Alan Gillespie**, University of Washington, presented several environmental applications, including determining ages of clear cuts and forest regrowth, climatological studies in Tibet, and stream-temperature determinations. **Susan Ustin**, (University of California, Davis), described vegetation studies, focusing on agricultural crop monitoring and classification using ASTER data in the California Central Valley. **Jeff Kargel**, (USGS), presented a talk on the Global Land Ice Measurements from Space

(GLIMS) project, that is using ASTER data to monitor thousands of glaciers worldwide. The project is a collaboration between 24 international organizations. **Dave Pieri** (JPL) spoke on volcano monitoring using ASTER. Several unique capabilities were highlighted, including mapping SO_2 emissions, determining lava-dome physical characteristics, and hot-spot mapping. **Mike Ramsey** (University of Pittsburgh) described the Urban Environmental Monitoring project he leads. The goal of the project is to characterize and monitor 100 cities around the world using a variety of data types.

The workshop presentations are available on CD. Please send your request to *howard.tan@jpl.nasa.gov*



This image of Mt. Usu volcano is dominated by Lake Doya, an ancient volcanic caldera. On the south shore is the active Usu volcano. Friday, March 31, 2000, more than 11,000 people were evacuated by helicopter, truck, and boat from the foot of Usu. The volcano began erupting from the northwest flank, shooting debris and plumes of smoke streaked with blue lightning as high as 2,700 meters (8,850 feet) into the air. Although no lava flowed from the mountain, rocks and ash continued fo fall after the eruption. This was the seventh major eruption of Mount Usu in the past 300 years. Fifty people died when the volcano erupted in 1822, its worst known eruption.

CCSDS Lossless Data Compression to be Available in HDF-4 and HDF-5

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EOSDIS manages data from NASA's past and current Earth science research satellites and field measurement programs, providing data archiving, distribution, and information management services. Over two terabytes of data are being produced by the EOS project each day. The transmission and archiving of such an unprecedented amount of data requires tremendous processing time, computer storage, and I/O bandwidth. One technique that can reduce data storage and network requirements without compromising data fidelity is lossless data compression.

The most commonly used lossless data compression techniques are based on the Lempel-Ziv-77 (LZ77) algorithm (e.g., gzip or its variations). This technique, however, generally yields poor compression ratios on data originating from spacecraft instruments. A second well-established technique is arithmetic coding (e.g., JPEG arithmetic coding). This technique works on most types of data, but exhibits relatively slow speed due to the need to update statistics during the process. The Consultative Committee on Space Data Systems (CCSDS) has adopted the extended-Rice algorithm as the recommended compression standard for international space applications. This technique was developed specifically for science instrument data through a joint effort between NASA GSFC and the Jet Propulsion Laboratory (JPL), based on requirements for high speed real time processing, low complexity, and quick adaptation to statistics. It has been implemented for many space missions in both instruments and data systems and base-lined for many future satellites as well.

In 1998, the Earch Science Technology Office (ESTO) / Earth Science Data and Information System (ESDIS) supported a prototype study to evaluate the performance of these different data compression techniques applied to EOS data. The performance of different lossless data compression techniques was compared on typical EOSDIS HDF-EOS data files. Two measurements, speed and compression ratio (CR), were used as the comparison criteria. The algorithms evaluated were the CCSDS lossless data compression (*Sz*), Gzip (*Gz*), Unix compress (*Cz*), and JPEG Arithmetic coding (*Az*). They were tested on a Sun Sparc20 workstation running the Unix operating system. The prototype study results demonstrated that CCSDS lossless data compression was superior to the other techniques in compression ratio and compression speed. **Table 1** shows the summary comparison results. Values in the table represent the averages over all the science data products tested.

Between 1999 and 2001, a further study on the feasibility of using CCSDS compression for real-time processing of EOS data was performed. Gigabytes of MODIS real sensor data were tested on an EOS Core System (ECS) operational machine. The results showed that the Sz compression time on the ECS production machine for a typical set of MODIS products (one granule including 1-km, 500-m and 250-m resolution data) was about 3 minutes. In comparison, it took almost one hour to compress the same data sets using Gzip. Only the Sz compression speed was suitable for the ECS operations, since the compression time per granule would be relatively small (~10%) compared to the time required to generate one granule of Level-1B data from Level 0 data. A scalability analysis

Table 1. Phase I Result Summary

	Sz	*Gz*	*Cz*	*Az*
CR	3.24	2.44	2.06	2.38
Compress (seconds)	353	8112	1973	10516
Decompress (seconds)	394	1264	790	7341

model was established by Daniel Menasce (George Washington University) to assess the cost savings of using CCSDS lossless data compression in the ECS operational system. The analysis was done based on the data volumes archived and distributed at the GSFC DAAC. The scalability model was used to assess cost savings of using Sz as a data compression algorithm in two scenarios: (1) SZDC - compress before storing and distribute in compressed form; and (2) SZDU - compress before storing and uncompress before distributing. SZDC saves bandwidth and network transmission time over SZDU but requires users to decompress files. It was determined that substantial cost savings could result from the use of hardware tape compression (1.5:1 compression) for Level 0 data products, and Sz compression for Level 1 and higher data products.

Based on the results, ESDIS recommended implementing the lossless data compression algorithm, *Sz* into the National Center for Supercomputing Applications (NCSA) Hierarchical Data Format (HDF) library. EOSDIS uses HDF-EOS, an extension to HDF, for archiving and distributing EOS data. HDF includes I/O libraries and tools for analyzing, visualizing, and converting scientific data. The current version of HDF-4 already supports lossless data compression algorithms – Run Length Encoding (RLE), Skipping Huffman (SKPHUFF), and Gzip compression (Lempel/Ziv-77 dictionary coder, named Deflate). The current version of HDF-5 supports Gzip compression only. Implementing the CCSDS lossless data compression into the HDF library provides a transparent method for users to capitalize on reduced data volumes since the HDF library contains an interface for storing and retrieving compressed or uncompressed data.

After two years of collaboration between NASA, NCSA, and the University of Idaho (the current license holder of the Sz license), CCSDS lossless data compression will now be incorporated into HDF. HDF-5 Release 1.6, to be released in June, 2003, will include support for CCSDS lossless data compression (Sz), along with the supporting utility programs. The next release of HDF-4, to be released in summer 2003, will also include support for Sz.

Pre-configured and pre-compiled HDF binaries will have Sz enabled, and will support data sets with 1-24 bits/pixel, 32 bits/pixel, and 64 bits/pixel. Sz source code and Sz binaries will also be available for download from NCSA. Applications will enable Sz by setting an optional filter when a dataset is created. Once enabled, data will be automatically compressed and decompressed with Sz during I/O. Sz distributed with HDF products will be free for non-commercial use, to both encode (compress) and decode (uncompress) data. Commercial users, however, may use the software only to decode data, and will need to acquire commercial licenses to distribute an Sz-based encoding software product.

Further details on Sz usage will be available from the NCSA HDF web site.

Aqua Mission Sponsors 2003 Engineering Competition

— Steve Graham, Stephen.M.Graham.2@gsfc.nasa.gov, Aqua Outreach Coordinator, Goddard Space Flight Center
— Claire Parkinson, Claire.L.Parkinson@nasa.gov, Aqua Project Scientist

On April 26, 2003, the Aqua Project Science Office, along with the NASA Goddard Space Flight Center Education Programs Office, EOS Mission Operations Office, Morgan State University, DuVal High School, and the Baltimore Museum of Industry, sponsored the Aqua Engineering Competition for High School students. The competition consisted of two rounds of problem solving, a qualifying long-term problem where teams had 10 weeks to solve a real-world Aqua problem, and a short-term hypothetical problem that had to be solved in 90 minutes.

In the competition's first round, teams from within Goddard's service region (Washington D.C. to Maine) were asked to determine the likely cause of a sudden increase and decrease that occurred in Aqua's solar array current and resulted in the spacecraft entering into "safe mode" during its first month of operation. A total of 12 entries were received and evaluated and the top five teams were selected as finalists. These finalists were then invited to DuVal High School for the second and final round of the competition, which occurred on April 26. Four high school teams from Maryland and one team from Connecticut were the five finalists and were tasked with determining how best to operate a supposed malfunctioning Solid State Recorder (SSR), including calculations for data loss based on specific SSR temperatures and bit error rates. The five finalist teams analyzed, sorted, and crunched data using their problem-solving skills, then used a laptop to make a final PowerPoint presentation to the judging panel.

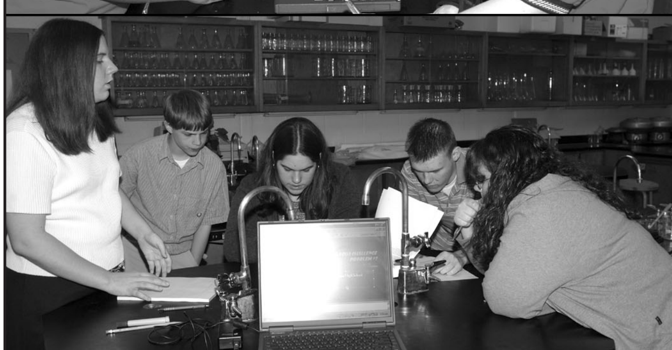
After the presentations were made, all the teams, parents, judges and facilitators made their way across the street to the Goddard Visitor Center where everyone was treated to lunch and presentations by the sponsoring agencies. Meanwhile, the judges were hidden away to tally up the round two scores and ultimately determine the winners. At the end of the day, all the teams and parents were treated to a personal tour of the EOS Mission Operations Center, hosted by Paul Ondrus, the EOS Mission Operations Director.

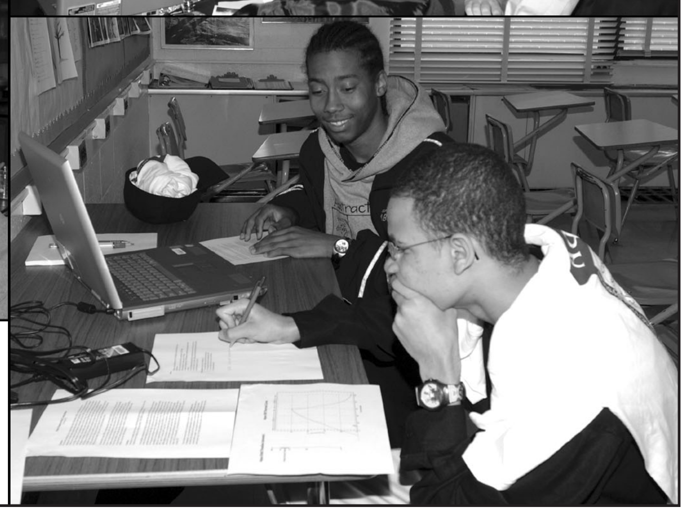
The Grand Prize, a state-of-the-art PC or Apple Macintosh computer system complete with a large assortment of supporting software, was awarded to the six-member team of Perry Hall High School in Baltimore, Maryland.

The First Runner-Up team, from the Applications and Research Laboratory High School (Red Team) of Ellicott City, Maryland, was also awarded a PC or Apple Macintosh system with software.

Tourtellotte Memorial High School of Grosvenordale, Connecticut, placed a very impressive third, and Chopticon High School of Morganza, Maryland, and DuVal High School of Lanham, Maryland, rounded out the field of very impressive teams. In addition to the first and second place awards, Palm Pilots, shirts, and well-deserved trophies were given to all members of all five finalist teams.

NASA congratulates all the teams for impressive performances during an enjoyable day of competition and education. Many thanks to the following key contributors for all their hard work: Claire Parkinson, Aqua Project Scientist; Ken Anderson, Aqua Engineer; Steve Graham, Aqua Outreach Coordinator; Ron Erwin, Goddard Education Programs Office; Ana Swamy, Morgan State University; Eugene Hoffman, Morgan State University; Dereje Seifu, Morgan State University; Susan Maule, Baltimore Museum of Industry; Lynn Hardin, DuVal High School; and finally Paul Ondrus, EOS Mission Operations Director, for graciously providing the funding for the competition.





(From Left to Right, Top to Bottom) Aqua Project Scientist Dr. Claire Parkinson introduces the teams to the Round 2 problem; Welcome Poster; Ron Erwin of the GSFC Education Programs Office informs the student teams, coaches, and parents about the day's schedule and activities; the first place team from Perry Hall High School of Baltimore, Maryland; Aqua Outreach Coordinator Steve Graham explains the solution to the Round 1 problem; the second place team from the Applications and Research Laboratory High School of Ellicott City, Maryland;the third place team from Tourtellotte Memorial High School of Grosvenordale, Connecticut; the fourth place team from Chopticon High School of Morganza, Maryland; the fifth place team from DuVal High School of Lanham, Maryland.

SEEDS Update

— Kathy Fontaine, Kathy.Fontaine@nasa.gov, NASA Goddard Space Flight Center

The Strategic Evolution of Earth Science Enterprise Data Systems (SEEDS) group held its third public workshop in Annapolis, Maryland, on March 18–20, 2003. With nearly 100 in attendance, from government agencies, private industry, and universities, this was our most well-attended and successful workshop to date. The two primary goals of this workshop were to:

1) give the data provider and science user communities the opportunity to respond in person to the draft set of recommendations prepared by the SEEDS Formulation Team;
2) and to begin dialog on the next phase of formulation: preparation for implementation of a SEEDS Program Office.

The draft set of recommendations was reported in the November / December 2002 *Earth Observer*, and stems from the work of seven study teams who were tasked to look at a specific aspect of data systems in a distributed, heterogeneous environment (namely, levels of service, standards for near-term and longer-term missions, data lifecycle and long-term archive, reuse, and reference architectures, technology infusion, and metrics planning and reporting). Each study team had a set of objectives and assembled a team representative of data-service providers, users, and other data-systems experts. Members of the Earth Science Information Partner (ESIP) Federation were involved in every study team, and contributed greatly to the development of the recommendations. While the formal comment period has expired, the draft is still available via the SEEDS homepage (*lennier.gsfc.nasa.gov/seeds/index.html*), and comments are always welcome.

Eighty-nine items were sent in over the course of the four months that the recommendations were officially open for comment. Comments ranged from general agreement or disagreement with certain points to specific wording suggestions. All comments are currently being processed, and answers to each comment will be sent back to the originator.

Mary Cleave, Deputy Associate Administrator for Earth Science (Advanced Planning), opened the meeting with a presentation about Code Y's plans for the next decade. **Martha Maiden**, Program Executive, presented the status of the data roadmap being created by Code Y as a way to link data activities to research, applications, missions, and other Code Y activities. Then **Stephen Wharton**, SEEDS Formulation Manager, presented his goals for the workshop. Other invited speakers included **Dave Jones**, President of the ESIP Federation, who spoke about Federation goals and areas for cooperation with SEEDS; **David Etter** from the Bay Area Shared Information Consortium (BASIC), who presented his work on standards; **William Johnston**, senior scientist at Lawrence Berkeley National Laboratory, who spoke about the Global Grid Forum standards development process; **Cheryl Craig** from the HIRDLS project, who spoke from the science team perspective about lessons learned in developing standards; and **Joseph Coughlan** from NASA Ames Research Center, who talked about technology infusion efforts in his organization. All presentations from this workshop are available via the link to the third workshop.

For the Formulation Team, work continues. After completing the Draft Recommendations Document, the team will be busy welcoming the Research, Education, and Applications Solutions Network Cooperative Agreement Notice (REASoN CAN) awardees to the working groups, finalizing their charters, and beginning their work. We are also planning for a workshop in the fall to welcome the REASoN winners and bring them up to speed on SEEDS.

Kudos

Glaciers and a Stream Named for EOS Scientists

Feature Name: Bindschadler Glacier
Latitude: 77º58´S; *Longitude*: 162º09´E
Description: A glacier in the Northwest part of Royal Society Range, Victoria Land, flowing north between Table Mountain and Platform Spur to join Emmanuel Glacier. Named by US-ACAN in 1992 after glaciologist **Robert A. Bindschadler** of the NASA Goddard Space Flight Center; from 1983 a principal investigator for the United States Antarctic Research Program (USARP) studies of the West Antarctic Ice Sheet, including dynamics of ice streams in the Siple Coast area, their interaction with the Ross Ice Shelf, and the role of polar ice sheets in global climate change. Bindschadler is a member of the Landsat TM Instrument Team.

Feature Name: Bindschadler Ice Stream
Latitude: 81º00´S; *Longitude*: 142º00´W
Description: An ice stream between Siple Dome and MacAyeal Ice Stream. It is one of several major ice streams draining from Marie Byrd Land into the Ross Ice Shelf. The ice streams were investigated and mapped by USARP personnel in a number of field seasons from 1983-84 and named Ice Stream A, B, C, etc., according to their position from south to north. The name was changed by US-ACAN in 2002 to honor **Robert A. Bindschadler**.

Feature Name: Shuman Glacier
Latitude: 75:154S; *Longitude*: 139:304W
Description: Glacier about 6 miles long draining through the Ruppert Coast north of Strauss Glacier. Named by US-ACAN after **Christopher A. Shuman**, NASA Goddard Space Flight Center, Greenbelt, MD, a field and theoretical researcher in the West Antarctic Ice Stream area from the 1990s to present. Shuman is a member of the IceSAT Instrument Team.

The Earth Observer staff and the entire science community wish to congratulate Drs. Bindschadler and Shuman for these outstanding accomplishments.

National Academy of Sciences Election

The National Academy of Sciences recently announced the election of 72 new members and 18 foreign associates from 11 countries in recognition of their distinguished and continuing achievements in original research. Among those honored was **Judith L. Lean**, a research physicist in the space science division of the Naval Research Laboratory, Washington, DC. Lean is a member of the SORCE Science Team.

The Earth Observer staff wishes to congratulate Dr. Lean on this outstanding accomplishment.

Earth's Hidden Waters Tracked by GRACE

— *Alan Ward, alan_ward@ssaihq.com, EOS Project Science Office, NASA Goddard Space Flight Center / SSAI*

The Gravity Recovery and Climate Experiment (GRACE) mission, the first Earth System Science Project (ESSP) mission launched by NASA in March of 2002, will produce extremely accurate maps of the Earth's gravity field. This information may be used to track changes in continental water storage on a global scale. GRACE is able to sense changes in the Earth's gravity field over a given time period. Changes in the Earth's gravity field arise in response to changes in the mass distribution both on and beneath the Earth's surface. It turns out that water movement (both of surface water and groundwater) is one of the major causes of fluctuations in mass on the Earth's surface. Thus, if the effects of other causes of mass change (the atmosphere, the oceans, and rebound from the weight of glaciers) can be removed, one should be able to deduce water storage changes over the continents from a gravity measurement. Introducing additional model information on soil moisture and other components of the total water storage may allow for the portion of the total water storage change attributable to groundwater (aquifer) changes to be isolated, which could be extremely useful in places where monitoring networks are sporadic or nonexistent and be a very powerful new tool for applications such as water resource planning.

Introduction

Viewed from above, our home planet is a "blue marble" with an abundance of water on its surface. Yet, only a small amount of this water is fresh and suitable for consumption by plants, animals, and humans. Potable water availability, quality, and conservation issues impact every nation on Earth and are becoming ever more important as population increases and other natural and manmade changes place more and more demand on these precious resources. Surface water includes both flowing water in streams and rivers, and impounded water in soil (soil moisture), natural lakes, polar ice caps, and manmade reservoirs. It also includes important seasonal variations caused by annual snowfall. Groundwater is the other component of total water storage and includes the large amounts of water stored beneath the Earth's surface in aquifers. Besides supplying water for drinking and other domestic uses, surface and aquifer waters are essential for power generation and irrigation. Plants and animals also depend on soil moisture and surface water. Furthermore, groundwater sustains streams between episodes of surface runoff, and snowmelt recharges the other stocks of water.

Since water availability is such a vital societal need, it is very important to better quantify water storage changes over the continents, particularly changes in groundwater storage. For example, it is well documented that the water level of the High Plains aquifer, which encompasses a large portion of the Midwestern U.S., has been steadily declining for the past few decades and it is believed that similar scenarios are playing out all over the world. The culprit is overuse; more water is taken out each year to meet the growing needs of society than is replenished by

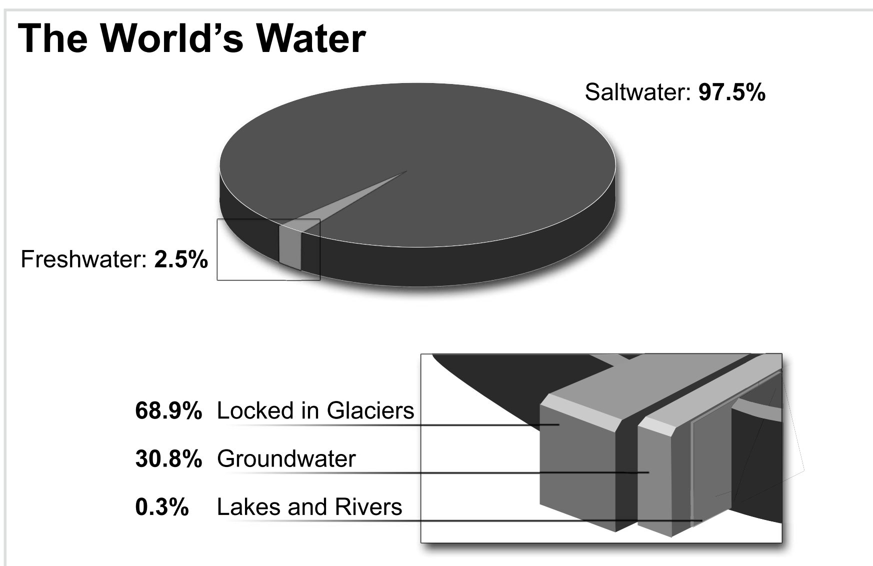


Figure 1: The pie graph shows that only a very small portion of the Earth's water is fresh. The closeup shows the breakdown of the fresh water supply. Almost a third of the world's fresh water is groundwater — stored in underground aquifers. Hence, GRACE's expected ability to monitor changes in these unseen water reserves from space is very significant.

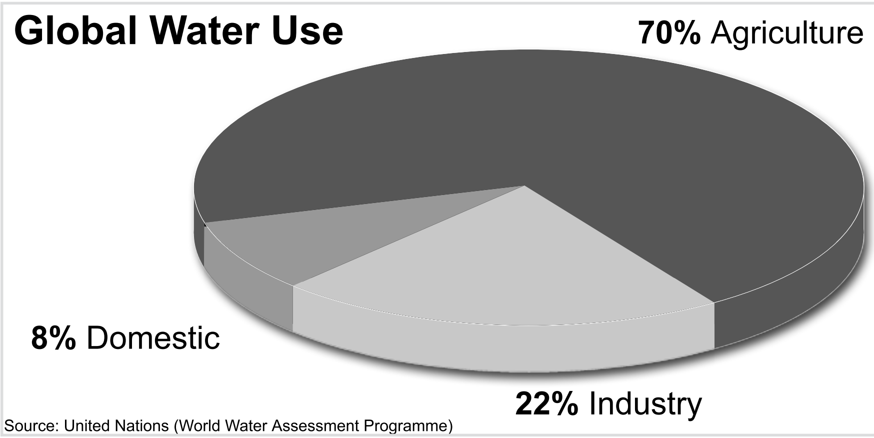


Figure 2: This graph shows that agriculture places the largest demand on the world's available water resources. Many agricultural applications draw their water from underground supplies. The continued viability of agriculture in some areas of the world critically dependent on these aquifers.

nature. To date, however, the influence of climate and meteorological phenomena on water storage changes is not well understood, and as a result models still do a poor job of representing water storage changes. In large part, this is due to a lack of reliable information. Historically, it has proven very difficult to develop networks for gathering terrestrial water storage data. And even the data that do exist are not really sufficient. Current ground-based water storage measurement techniques are labor intensive and provide only point estimates of water storage. As a result, most of the world's aquifer systems are not surveyed regularly and methodically, which renders assessing regional changes in groundwater levels tedious or impossible.

Remote sensing has been touted as a possible solution to this problem. The vantage point of space allows for global- and synoptic-scale measurements to be obtained, and makes it more practical to track water storage changes on a larger scale. The Advanced Microwave Scanning Radiometer for EOS (AMSR-E) onboard the Aqua spacecraft, for example, has the capability to examine surface soil moisture from orbit and will result in improved representation of surface soil water storage in models. However, it is unable to penetrate beyond the top few centimeters to sense deeper soil moisture or groundwater.

Researchers will soon have a new tool to study subsurface water storage fluctuations in their arsenal. Their new weapon comes from what might at first seem like an unlikely source. In March of 2002, NASA launched GRACE — the first of the ESSP missions. Its five-year mission is to map the Earth's gravity field with unprecedented accuracy every 30 days.

Gravity 101

If Earth were a smooth sphere composed of similar elements or ingredients, there would be no need for a GRACE mission. The assumption made in most introductory physics courses that the acceleration due to Earth's gravitational field has a constant value would indeed be correct — end of story. The reality, however, is that Earth is anything but smooth and uniform, and the gravity field is continually changing, mostly due to variations in water content as it cycles between the atmosphere, oceans, continents, glaciers, and polar ice caps. GRACE will reveal the broad features of the Earth's gravitational field over land and sea; it will also allow for these smaller scale features to be identified and studied with unprecedented accuracy and it will show how the Earth's gravity field varies with time. The unique design of the GRACE mission is expected to lead to an improvement of several orders of magnitude in these gravity measurements and allow much improved resolution of the broad to finer-scale features of Earth's gravitational field over both land and sea.

The Earth's gravity field consists of two components: a mean (or long term average) component and a time variable component. The mean component of the gravity field is that portion of the total gravity field resulting from mass distributions that remain virtually unchanged over millions of years like the mass of the Earth or the locations of continents — phenomena that are more or less constant for purposes of computing the gravitational field. In contrast, the time variable component of the gravity field is that portion of the gravity signal caused by mass fluctuations that occur on much shorter time scales including changes in groundwater, ocean surface height, and atmospheric mass. Although the mean gravity field is of considerable value in understanding the structure of the Earth and helping to reveal aspects of ocean circulation, it is the time variations in the gravity field, in particular those caused by water storage changes, that are of interest in this study.

The workings of GRACE

GRACE is different from most Earth observing satellite missions — Terra and Aqua for example — because it doesn't carry a suite of independent scientific instruments on board. It does not make measurements of the electromagnetic spectrum like many of the instruments currently flying in space. Instead, the two GRACE satellites themselves act in unison as the primary instrument. Changes in the distance between the twin satellites are used to make an extremely precise gravitational field measurement.

The two identical satellites orbit one behind the other in the same orbit plane at an approximate distance of 220 km (137 miles). As the pair circles the Earth, areas of slightly stronger gravity (greater mass concentration) affect the lead satellite first, pulling it away from the trailing satellite. The change in distance would certainly be imperceptible to our eyes, but an extremely precise microwave ranging system onboard GRACE is able to detect these miniscule changes in the distance between the satellites. A highly accurate accelerometer, located at each satellite mass center, measures the non-gravitational accelerations (such as those due to atmospheric drag) so that only accelerations caused by gravity are considered. Satellite GPS receivers determine the exact position of the satellite over the Earth to within a centimeter or less. Scientists can take all this information, and use it to construct maps of the gravity field over the Earth's surface once every thirty days during the planned five-year mission.

Tracking water storage change over continents from space

GRACE data will do more than just produce a more accurate gravitational field plot, however. The measurements from GRACE have important implications for improving the accuracy of many scientific measurements related to climate change—hence, GRACE is also a climate experiment as its name implies. Accurate gravitational measurements are a critical input to many scientific models used in oceanography, hydrology, geology, and related disciplines and, for this reason, the Earth Science community is excited about potential applications for GRACE data. One of the most intriguing uses of data is expected to be using data from GRACE to track changes in water storage over terrestrial regions.

Matt Rodell at the Goddard Space Flight Center and Jay Famiglietti at the University of California at Irvine have done extensive work to prove this concept, following up on work that had been done by John Wahr at the University of Colorado. Wahr demonstrated the potential for using GRACE data to monitor water storage by deriving a simulated GRACE gravity field and then separating out the water storage component of the signal. Rodell and Famiglietti's work used 10 modeled global time series of water storage to study water storage change for 20 river basins of varying size around the world and determined how successful GRACE will be in detecting the variations. The findings indicate that data from GRACE should be able to be used to decipher monthly water storage changes over continents for areas of approximately 200,000 km^2 or larger. They then conducted a study over the state of Illinois. Illinois has an area of 145,800 km^2 (below the minimum threshold for GRACE to detect monthly water storage changes) but it has the advantage of having a rather extensive record of observed data. The results in Illinois had to be scaled up to larger regions by assuming conditions in the surrounding area are similar to those in Illinois. Again, the results were encouraging and indicated that GRACE should be able to detect monthly water storage changes over areas larger than 200,000 km^2. Rodell and Famiglietti are excited to see GRACE data begin to flow this summer, so that they can verify their findings with actual data.

GRACE measurements by themselves, however, are not able to distinguish whether a change in gravity results from a change in water mass, a change in the mass of the overlying atmosphere, or a change in the underlying solid Earth. Outside information is needed to estimate the contribution of the other components to the total gravity measurement. To measure water storage changes using the GRACE-technique, monthly average gravity fields are desired. Therefore, any gravity variations with a timescale of a month or less have to be removed before the data is released for use, during the calculation of the original orbit and gravity solution. The GRACE science team uses a complex atmospheric model and an ocean model to account for changes in gravity that arise from such phenomena as ocean tides and the atmosphere-a technique known as dealiasing. This can be thought of as "correcting" the raw gravity field for the effects of the daily weather.

Now, the gravity measurement is ready for use in hydrological applications. Any variations that remain have a timescale of one month or larger (equal to or greater than the phenomena being observed) and can be dealt with by scientists after they receive the data from the GRACE science team. Using various model simulations of the atmosphere and the solid earth, the effects not attributed to changes in water storage can be removed and the "corrected" gravity field now represents only the portion that is attributed to the mass of water stored in a particular region at a given time. This can then be converted to an equivalent water height. Two of these measurements taken at different times can be used to study changes in water storage in a particular region.

Sources of Error

But it's not really as simple as subtracting the other components from the total gravity measurement. It would be as simple as that if these models were perfect representations of actual conditions—but they aren't. Each model used in this process is just a simulation of the actual conditions and thus less than perfect. There has to be some way to account for how much these model imperfections impact the final water storage measurement. So, what the scientists have to do is devise a way to look at how much error each of the external models used in this calculation introduce to the final total water storage estimate. A GRACE water storage estimate could be rendered useless if the total error introduced by removing these other components is greater than the magnitude of the actual water storage estimate.

In addition to errors introduced by removing each of the other components of the total gravity measurement, the GRACE instrument itself introduces yet another source of error due to all of its various mechanical components. So to figure out the total error introduced to the water storage estimate, one has to account for the combined effects of the various model estimates and the instrument itself. It turns out that, in general, the instrumental errors are the primary impediment to using the GRACE-technique to estimate water storage in areas smaller than 200,000 km^2 and over shorter time scales. Atmospheric mass errors become dominant at larger scales, but aren't large enough to prevent the retrieval of meaningful water storage change measurements.

Limitations to the Technique

Because it takes time for the GRACE satellites to fly over parts of the Earth, the total magnitude of the water storage change at an instantaneous time cannot be determined using this technique. Only the change in water storage over a given region for a given time interval is obtainable. So, as an example, one could use this technique to examine the change in water storage over the Mississippi River basin during a chosen time interval, but one could not determine the height of the water table in the Mississippi River basin at the specific time the measurement was obtained. In fact, in order to determine water storage change over a region, GRACE measurements from two distinct time periods must be used.

Rodell and Famiglietti's two studies considered areas ranging in size from the state of Illinois up to entire river basins such as the Amazon and the Mississippi and looked at monthly, seasonal, and yearly time intervals for all of these regions. They found that, generally speaking, the planned GRACE-technique will be more accurate for larger areas over longer time intervals. For example, an area the size of Illinois (145,800 km^2) will usually not be able to have month-to-month water storage changes detected using the GRACE-technique, but it is more likely to have seasonal (three-month periods) changes detected, and even more likely to have annual changes detected. In contrast, an area the size of the Mississippi River basin (3,165,500 km^2) will likely be able to have water storage change detected at monthly, seasonal, and annual time intervals. As one might expect, the method will be most effective when the actual magnitude of the change being observed is large. So, even in larger areas, the GRACE-technique will be most effective when there is a large amount of variability in water storage over the chosen time interval. In many locations, changes between seasons have the highest magnitude, and thus seasonal water storage change may be easiest to detect using the GRACE-technique.

Honing in on groundwater

When combined with still more outside information from other sources, the GRACE-technique may be taken a step further and used to focus in on groundwater changes. This raises the very exciting possibility of allowing changes in aquifer water storage to be tracked from space. Rodell and Famiglietti have demonstrated this potential by examining data from the U.S. High Plains region. In order to isolate the groundwater component of total water storage change, the contribution from all of the other components to total water storage change have to be determined and removed. The main contributors to total water storage change over continents are changes in soil moisture, snow water, and reservoir storage (meaning, surface water that is restrained and well monitored). In the work they did in Illinois, the two scientists found that the contributions to the total water storage change resulting from reservoir storage (not including unregulated surface water flow as of yet) and snow water were usually insignificant relative to changes in soil moisture and ground water. They make the assumption that the same is true of the High Plains region. That leaves soil moisture as the sole component that has to be removed to get at elusive groundwater changes. It turns out that the U.S. High Plains, unlike most aquifers around the world, has been well sampled and studied, meaning that lengthy time series of soil moisture change exist. This allows for soil moisture change over time to be estimated fairly accurately using models. The soil moisture contribution can be removed and the remaining change in water storage is that resulting from changes in groundwater.

Further refinements should allow for increasingly accurate estimates of groundwater storage using the GRACE-technique. As time progresses, soil moisture simulations will become more and more realistic as data from additional sources (such as AMSR-E and new surface observations) are assimilated into the models. Future efforts will also separate water stored in the so-called intermediate zone (between the lowest level of soil moisture modeled and the top of the water table), isolating the groundwater component even more accurately. Intermediate zone storage is still not well understood and more work is needed to refine our understanding of this component of total water storage so that it can be represented realistically in models. Finally, the proposed follow-on mission to GRACE will replace the current microwave ranging system with a laser interferometer, greatly reducing instrumental errors, and allowing viable measurements over areas as small as 10,000 km^2.

Using modeled soil moisture adds yet another source of error that must be accounted for when attempting to use the GRACE-technique to isolate changes in groundwater from the total water storage change. In actuality, over an area the size of the High Plains, the error in the soil moisture estimate turns out to be the largest source of error—dominating atmospheric mass model error and instrumental effects mentioned above. However, the error does not appear large enough to render the GRACE-technique ineffective.

Conclusion

From its satellite platform far above the Earth, GRACE will likely provide estimates of groundwater storage changes all over the world. Preliminary studies have shown that the GRACE-technique will allow for estimates of annual groundwater change over the High Plains to within about 8.7 mm of their actual value. While there is some question whether this represents a major improvement for a densely monitored aquifer like the High Plains aquifer, as mentioned above, most aquifers around the world are not nearly as well sampled as the High Plains aquifer. What's more, even over more extensively sampled areas, the prospect of a technique that is less labor intensive and does not require an extensive network of wells that is equal to or perhaps slightly better than what is currently available is quite intriguing. GRACE may help to reveal groundwater depletion in areas of the world where it is not systematically documented or where it is not disclosed for political reasons. Overall, the GRACE-technique seems to offer an objective, unbiased method for monitoring water storage changes on a global scale.

As this new information from GRACE becomes assimilated into forecast models, the simulations produced will become more and more realistic and useful for predicting future conditions. This will lead to forecasts with increased accuracy and longer lead times, so that by decade's end water resource planners will have access to much more detailed and dependable information than they have at present. This will lead to improved ability to regulate water resources and make sure that sufficient quantity is present for the many needs of society—irrigation for agriculture, municipal supplies, and industry, just to name a few. It should also lead to rather substantial improvements in our ability to predict, plan for, and respond to extreme events, such as floods and drought.

NASA's Earth Science Enterprise Sponsors Creative Problem Solving Competition

— *Charlotte Griner, cgriner@pop900.gsfc.nasa.gov, EOS Project Science Office*
— *Steve Graham, graham@pop900.gsfc.nasa.gov, EOS Project Science Office*

Over 13,000 students, coaches, parents, and spectators gathered at the University of Iowa in Ames, May 28-31 for the 24th Annual Odyssey of the Mind World Finals, an international event where teams come together to compete for the World Championship in their long-term problem and division. Through a grant, NASA's Earth Science Enterprise sponsored a problem titled "A Scene from Above," one of the five long-term problems associated with this year's competitions. The students were challenged to design, build and run three small vehicles to transport items from an orbit area to an assembly station in space. The vehicles were added to a three-dimensional representation of a scene of the Earth as viewed from space, and as the vehicles were added, the scene changed. The vehicles were required to be powered in different ways; one vehicle carrying its own energy source while the other two vehicles were powered by the momentum created by different sources.

During the 2002/03 school year millions of kids from across the world brainstormed, built, revised and perfected their solutions with the hopes of advancing from regional and state association tournaments to the World Finals. A total of 127 teams competed for the top awards in the NASA-sponsored problem. Following are the first, second and third place winners in each Division:

Division 1

1. Sharon Elementary School, Team A, Charlotte, North Carolina
2. McKinley School, Rydal, Pennsylvania
3. Mantua Elementary School, Team B, Fairfax, Virginia

Division 2

1. Friendswood Junior High School, Friendswood, Texas
2. Churchville-Chili International School, Team A, Spencerport, New York
3. Shorecrest Preparatory School, Largo, Florida

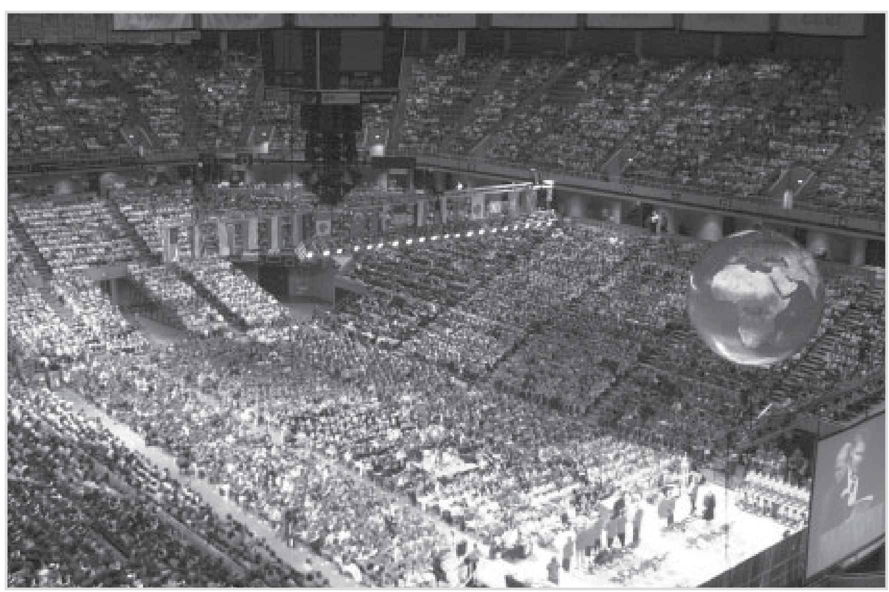
Division 3

1. Myers Park High School, Green Team, Charlotte, North Carolina
2. Brien McMahon High School, Norwalk, Connecticut
3. Pennridge High School, Green Lane, Pennsylvania

Division 4

1. Osrodek PsychoedukacjiI Damb, Gdansk, Poland
2. Georgia Tech University, Atlanta, Georgia
3. Lehigh University, Bethlehem, Pennsylvania

The Odyssey of the Mind and NASA partnership is a natural collaboration. Both organizations represent the best in innovation, teamwork and creative problem solving. ESE hopes to inspire some of those students to become future scientists and engineers. More information on the Odyssey of the Mind World Finals can be found at *www.odysseyofthemind.com/wf2003*



More than 13,000 students, coaches, parents, and spectators filled the Hilton Coliseum on Saturday evening, May 31 for the Odyssey of the Mind awards presentation and ceremonies.

Earth Science Education Program Update

— Ming-Ying Wei, mwei@hq.nasa.gov, NASA HQ
— Theresa Schwerin, theresa_schwerin@strategies.org, IGES

New Investigator Program (NIP)
Proposals Due: August 15, 2003

The New Investigator Program (NIP) in Earth science was established in 1996 to encourage the integration of Earth system science research and education by scientists and engineers at the early stage of their professional careers. The program, designed for investigators in Earth system science and applications at academic institutions and non-profit organizations, emphasizes the early development of professional careers of these individuals as both researchers and educators. The program encourages scientists and engineers to develop a broader sense of responsibility for effectively contributing to the improvement of science education and the public science literacy; it provides an opportunity for the investigators to develop partnerships and enhance their skills, knowledge, and ability to communicate the excitement, challenge, methods, and results of their work to teachers, students, and the public. Of particular interest is the investigators' ability to promote and increase the use of Earth remote sensing through the proposed research and education projects.

NIP proposals are openly solicited approximately every 18 months. The awards range between $80,000-$120,000 per year for a period of up to three years, For more information, see *research.hq.nasa.gov* under "Office of Earth Science (Code Y)." For more information, please contact Dr. Ming-Ying Wei, Manager, Education Programs, Office of Earth Science, mwei@hq.nasa.gov.

NSF Program Announcement for EarthScope Proposals

Proposal Deadline: July 16, 2003

The National Science Foundation (NSF) has released a Program Announcement inviting proposals for EarthScope Science, Education and Related Activities. Full details are available at: *www.nsf.gov/pubs/2003/nsf03567/nsf03567.htm*.

The EarthScope facility (USArray, San Andreas Fault Observatory at Depth [SAFOD]), and Plate Boundary Observatory (PBO) is a multi-purpose array of instruments and observatories that will greatly expand the observational capabilities of the Earth sciences and help advance understanding of the structure, evolution, and dynamics of the North American continent. The EarthScope observational facility provides a framework for broad, integrated studies across the Earth sciences.

Director, The GLOBE Program

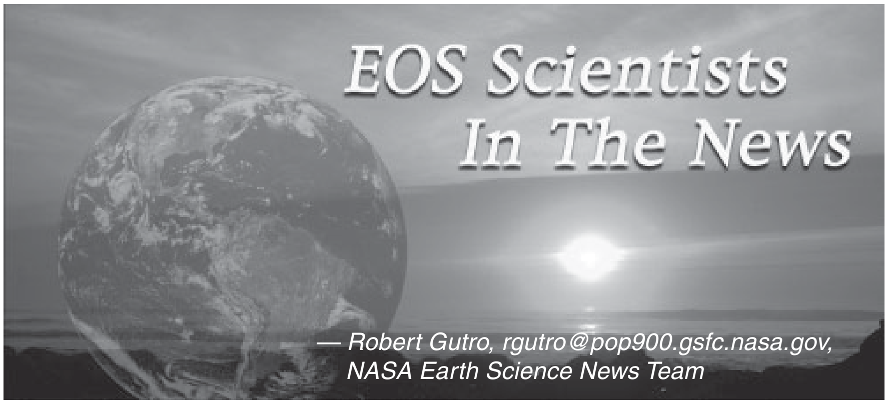
The University Corporation for Atmospheric Research (UCAR) has an opening for the position of Director, Global Learning and Observations to Benefit the Environment (GLOBE) Program. The GLOBE Program is a worldwide hands-on, primary and secondary school-based education and science program. It is a cooperative effort of schools, led in the U.S. by a Federal interagency program and supported by NASA, the National Science Foundation (NSF), the Environmental Protection Agency (EPA), and the U.S. State Department, in partnership with colleges and universities, state, and local school systems, and non-government organizations. Internationally, GLOBE is a partnership between the United States and 102 other countries. For full position description, see *www.fin.ucar.edu/hr/careers/uco.cfm?do=jobDetailExt&job_ID=72*.

U.S. Global Change Research Program Website — New and Improved

The U.S. Global Change Research Program has just updated its "New" page with a wide-ranging set of organized links to new online material. The page is usually updated monthly and provides an easy way to monitor important scientific developments without having to dig around dozens of different web sites. See the additions at *www.usgcrp.gov/usgcrp/new.htm.*

DLESE K-12 Earth Science Listserves

This web site provides information about Earth science/Geoscience education listservs in the United States. See *dlesecommunity.carleton.edu/k12/listservs*.



NASA Research Helps Highlight Lightning Safety Awareness Week, June 19, *Aboutweather, Der Wissenschaft (Germany)* - **Steven Goodman, Dennis Boccippio, Richard Blakeslee, Hugh Christian**, and **William Koshak** (all from NASA/Marshall) helped create a high-resolution world map showing the frequency of lightning strikes.

NASA Rainfall Measurement, June 15; T*he Huntsville Times, (Ala.)* - **Gary Jedlovec** (NASA MSFC) discusses the Cooperative Huntsville Area Rainfall Measurements (CHARM), a local precipitation-measurement network.

Study Suggests Ancient Oceans Had Low Levels of Oxygen, June 10, *Associated Press*, quotes **David Des Marais** (NASA/Ames) who is co-author of a study included in the June 5 issue of the journal **Nature**.

Spotlight on Ames Researcher, June 3, *Chicago Tribune*, column about NASA researcher **Azadeh Tabazadeh** (NASA/Ames)

Jet Writers in the Sky, June 2, *Knoxville News Sentinel, knoxnews.com* - **Pat Minnis** (NASA Langley) speaks about the contrail studies conducted during the 2001 air traffic shutdown.

NASA's Aqua Satellite Marks One Year, May 29, *Spacedaily.com* - **Claire Parkinson**, Aqua Project Scientist (NASA/GSFC) was quoted in this article on Aqua's first year. Aqua provided views of fires, snowstorms, typhoons, a volcanic eruption and dust storms.

QuakeSim, May 27, *KTVU-TV, CH 2 Oakland;* May 22, *KNBC-TV, Los Angeles, CA* — **Walt Brooks** and **Creon Levit** (NASA Ames) were interviewed about how JPL 'QuakeSim' program software will run on the biggest parallel supercomputer of its kind in the world at NASA Ames.

Students at Ames, May 24 and 25, *KCBS-AM, San Francisco* - **Jay Skiles** (NASA/Ames) was interviewed about students who will study Earth Science at Ames this summer.

Precipitation in the Southern U.S., May 20; *WHNT-TV Channel 19, Huntsville Ala.* - **John Christy, Gary Jedlovec** and **Bob Oglesby** (NASA MSFC) discuss precipitation and drought in the Southern United States.

Potential Pollution Dangers of the Air In Baghdad Due to Burning Oil, Thick Smoke and Sandstorms, March 27, *National Public Radio's, "All Things Considered"* - **Joel Levine** (NASA Langley) discusses the environmental impact of the burning Iraqi oil wells.

EOS Science Calendar

July 21 - 22, 2003

SEDAC User Working Group meeting, New York, NY. Contact: Robert Chen, bchen@ciesin.columbia.edu.

July 28 - August 1

"Earth Science for Safety" — 11th meeting of the ESIP Federation, Boulder, Colorado. URL: www.esipfed.org, Contact: Dave Jones, dave@stormcenter.com

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: Gary Gibson, Gary.G.Gibson @nasa.gov.

September 30

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.

December 4-6

SORCE Science Team Meeting, Sonoma, CA. Contact: Bob Cahalan, Robert.F.Cahalan@nasa. gov.

Global Change Calendar

2003

July 21 - 25

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

August 30 - September 6

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

September 8 - 10

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

September 23 - 26

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

November 10 - 14

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

December 9-12

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

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

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