



# THE EARTH OBSERVER

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## In this issue ...

### Meeting/Workshop Summaries

First CERES-II Team Meeting.....3

### Other Items of Interest

Update on Recent ESSP Mission Activities.....9

Landsat Celebrates its 15<sup>th</sup> Anniversary.....14

LP DAAC Release of MODIS Swath Reprojection Tool (MRTSwath) Software.....15

Kudos.....15  
Terrestrial Carbon Sinks Predicted from MODIS Satellite Data and Ecosystem Modeling.....15

### Regular Features

EOS Scientists in the News.....21

Earth Science Enterprise Education Program Update.....16

Science Calendars.....23

The Earth Observer Information/Inquiries.....Back Cover

## EDITOR'S CORNER

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Continued on page 2



## First CERES-II 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 first meeting of the new Clouds and the Earth's Radiant Energy System-II (CERES-II) science team was held on March 29-31 at the National Center for Atmospheric Research (NCAR) in Boulder, CO. Bill Collins served as host for the meeting. The new CERES science team includes members of the algorithm/data products team and also scientists who plan to use CERES data products in climate-system studies. The meeting was held jointly with the European Geostationary Earth Radiation Budget (GERB) team. GERB followed with a team meeting on March 31-April 2. This first CERES-II meeting was used to introduce the CERES data products to a broader climate community (e.g., NCAR climate modelers), to highlight the research plans of the new CERES team members, and to facilitate joint activities with the GERB International Science Team (GIST). CERES brings calibration and angular sampling capabilities to GERB, and GERB brings time-sampling capabilities to CERES. The CERES-II team and the NCAR community discussed methods to improve the testing of climate models using CERES observations at a range of time and space scales. The next CERES-II Science Team meeting will be held near Langley Research Center (LaRC) in Fall, 2004.

### Climate Program Overview

**Bruce Wielicki** (LaRC) reported on the state of the U.S. Climate Change Science Program (CCSP), NASA Earth Ob-

serving System (EOS), CERES, National Polar-orbiting Operational Environmental Satellite System (NPOESS), and NPOESS Preparatory Project (NPP). A National Research Council review indicated that the second draft of the CCSP Strategic Plan was much improved, but there is still no clear funding to implement the plan. The National Institute of Standards and Technology (NIST) workshop report now in press will be used to guide NOAA climate observations. Climate Data Records (CDRs) will be produced separately from Environmental Data Records (EDRs for near-real-time weather data). The Terra and Aqua missions continue to work well and the Tropical Rainfall Measuring Mission (TRMM) is likely to operate until at least 2006. All three of these missions have a CERES instrument onboard. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) lidar and CloudSat radar are expected to launch June 17, 2004 and fly in formation with Aqua. NPOESS, the merged NOAA/DoD weather satellite system, which will also be used for CDRs, is planned for launch in 2011. Copies of CERES (called the Earth Radiation Budget Sensor) are to be flown in the 1:30 p.m. sun-synchronous orbit. The plan is to use CERES Single Scanner Footprint (SSF) and Cloud and Radiation Swath (CRS) data products in near real time for EDRs and later re-analyze into CDRs. Since there will not be a CERES instrument on NPP, there is an approximately 50% chance of a data gap between CERES

on Aqua/Terra and NPOESS. The gap issue is one of overlap and intercalibration since instrument stability greatly exceeds absolute accuracy. The Global Energy and Water-cycle Experiment (GEWEX) Radiation Panel has reiterated its recommendation to eliminate the 50%-gap risk, and the U.S. Climate Variability and Predictability (CLIVAR) group and the CCSP Observations Working Group are expected to issue similar recommendations.

### CERES Overview

Bruce Wielicki presented a brief overview of CERES. He showed that current climate models do not capture the tropical longwave (LW) flux anomalies associated with the 1998 El Niño. He demonstrated the importance of overlapping radiation data sets for climate studies. Over the past 15 years, models showed less variability than the observations, indicating that the models are missing feedbacks, forcings, and a realistic representation of cloud physics. Wielicki illustrated the importance of instrument stability and calibration for climate research and showed that CERES has attained climate-level-accuracy. He described several important advances in CERES including the new CERES Angular Distribution Models (ADMs), which yield greatly improved instantaneous fluxes. The new CERES SSF fluxes derived with scene-dependent ADMs can be used to test climate and cloud-resolving models. Similar improvements are being achieved

through the use of geostationary narrowband data to accurately represent diurnal variations in the temporal interpolation algorithms. Overall, CERES is reducing of the major sources of error and has a target uncertainty of about  $2 \text{ W/m}^2$  in global net. By comparison, the uncertainty for the Earth Radiation Budget Experiment (ERBE) was about  $5 \text{ W/m}^2$  (heating) and was within its accuracy bound given calibration, angular-sampling, and time-sampling limitations.

#### **Terra/Aqua CERES Instruments and Calibrations**

**Kory Priestley** (LaRC) presented the health and calibration/validation status of the four CERES instruments on Aqua and Terra. The CERES Terra/Aqua instruments are functioning nominally. Edition2 Bi-Directional Scan (BDS) and ERBE-Like products are available from launch through June 2003 for the Terra/Aqua instruments. CERES is set to release the Terra July - December 2003 Edition2 BDS and ERBE-Like products. The Edition2 BDS and ERBE-Like products continue to demonstrate unprecedented stability of  $0.1\%$ /year for top-of-atmosphere (TOA) LW and shortwave (SW) fluxes as well as atmospheric window (WN)-channel radiances.

#### **ERBE-Like Fluxes**

**Takmeng Wong** (LaRC) gave an overview of the CERES ERBE-Like system including Edition2 data status, availability, and documentation. Wong also compared the Terra and Aqua ERBE-Like data products using the new Edition2 Aqua data set, which contains an on-orbit calibration correction to remove the LW drift found in Edition1 data.

#### **Cloud Properties**

**Patrick Minnis** (LaRC) presented CERES cloud algorithms and results. The objective is to provide a consistent cloud properties data set from TRMM, Terra, and Aqua that will relate cloud properties to the radiation budget; derive TOA, surface, and atmospheric radiation budgets; and provide data to initialize and validate climate- and weather-prediction models. He also described efforts related to satellite-instrument intercalibration, the cloud-mask algorithm, and cloud-retrieval methods for day, night, and over snow. He showed global retrievals of cloud properties and selected validation results. His algorithms retrieve a complete set of physical and microphysical cloud properties, but he offered several caveats concerning the use of the data. For example, the derived cloud microphysical properties at night should not be used; nighttime polar-cloud amounts are still uncertain; and optical depths over snow are very uncertain. Other limitations are given in the Data Quality Summary.

#### **ADMs**

**Norman Loeb** (Hampton University) presented an overview of the new CERES/Terra SW, LW, and WN ADMs used for estimating fluxes from radiance measurements. The new models are based on 2 years of global CERES/Terra rotating-azimuth-plane scan measurements and rely on coincident Moderate Resolution Imaging Spectroradiometer (MODIS)-based cloud properties from the CERES cloud group for scene identification. Regional monthly mean TOA flux uncertainties due to ADM errors are estimated to be less than  $1 \text{ W/m}^2$  (1-sigma) in both SW and LW regions. All-sky instantaneous

TOA flux uncertainties are estimated between  $10\text{-}15 \text{ W/m}^2$  for SW and  $5 \text{ W/m}^2$  for LW. When stratified by cloud type, the errors are factors of 2-5 smaller than those obtained using the ERBE ADMs. Loeb also showed that improvements in cloud screening based on high-resolution spectral MODIS measurements have a significant effect on cloud-radiative-forcing estimates compared to ERBE.

#### **Simple Surface Fluxes**

**David Kratz** (LaRC) presented the results from the Surface-Only Flux Algorithm (SOFA) Working Group's validation of CERES/Terra SSF fluxes. The SSF results were validated against surface measurements from several climate regimes including continental, coastal, island, desert, and polar. Both LW models achieved the desired accuracy and precision. Both SW models were in good agreement for clear-sky cases for the continental, coastal, and island sites, but the clear-sky-only SW model underestimated surface fluxes for the desert and polar sites. The all-sky SW model continued to show a large scatter when instantaneously matching CERES  $20\mu\text{m}$  field-of-view data to 30-minute average surface data due to noise caused by cloud spatial variability.

#### **Merged CERES/GEO Time Sampling**

**David Young** (LaRC) summarized the techniques used in CERES operational processing to produce Level 3 gridded and time-averaged data products. He emphasized the recent development of new instrument-specific narrowband-to-broadband (NB-BB) conversion models that are used to produce BB flux estimates from the NB geostationary imager (GEO) data. These

simulated BB fluxes are merged with the CERES observations to remove temporal sampling biases from the CERES time-averaged products. Co-located Visible-InfraRed Scanner (VIRS) and CERES observations were used to generate the NB-BB relationship over the full range of viewing geometries. Initial results indicated a reduction in flux-error estimates of about 30%. Young also showed the first comparison of Aqua and Terra monthly means (SRBAVG). The addition of GEO data resulted in improvements in the consistency of the Aqua/Terra monthly mean SW flux of more than  $20 \text{ W/m}^2$  in some regions. Global net fluxes remain largely unchanged (less than  $0.5 \text{ W/m}^2$ ) by the addition of the GEO data. The first 3 years of Terra SRBAVG are scheduled for public release in August 2004.

#### Terra CRS

**Thomas Charlock** (LaRC) described the status of Terra CRS ValR2, the CERES Surface and Atmosphere Radiation Budget (SARB) consisting of radiative fluxes at the surface, 500-hPa, 200-hPa, 70-hPa, and TOA. This SARB product was evaluated for 7 months of 2001, and will soon be released as Terra CRS Edition 2A. Inputs include MODIS cloud properties from the CERES Cloud Group, aerosols from MODIS Atmospheres and from the Model for Atmospheric Transport and Chemistry (MATCH) assimilation, and the Goddard Earth Observing System (GEOS-4) temperature, humidity, and wind assimilation data. SW, LW, and WN radiative flux profiles are calculated using a gamma function version of the Langley Fu-Liou radiative model. Fluxes are then constrained against the CERES TOA fluxes. Surface fluxes in the CRS product met accuracy goals for all but desert dust locations — dust will

be corrected in Edition2B.

#### Data Management

**Mike Little** (LaRC) reviewed the CERES Data Management status and described recent and upcoming data-product releases. He provided a brief explanation of the various data-product documents and spoke about lessons learned from past experiences with code development, and large-volume data products. **Sue Sorlie** (SAIC) of the Atmospheric Sciences Data Center (ASDC) described how to obtain a special science team member account for accessing data that have not yet been released to the public. ASDC delivered 13.6 TB of CERES data products in 2003.

#### Outreach

**Lin Chambers** (LaRC) gave an overview of the CERES education and public outreach effort, the Students' Cloud Observations On-Line (S'COOL) Project. She invited new and old members of the team to get involved by serving as a resource to local teachers, visiting S'COOL participants, and helping with translation efforts. The S'COOL website has recently been averaging over 400 hits/hour, with visitors from 80 countries. More than 32,000 observations have been collected from participants in 47 countries.

#### Invited Presentations

**Kevin Trenberth** (NCAR) presented an overview of the flow of energy through the Earth's climate system, its relationships with weather and climate phenomena, and the skill of current climate models in accurately simulating the energy flows and water cycle-processes. A fundamental question for climate

science is to what level the Earth-atmosphere system is in radiative balance. A lack of radiative balance on annual or longer time scales implies energy storage in (or release from) the oceans. He reviewed the processes that transport energy from low to high latitudes, and the transformations of energy between potential, sensible, latent, kinetic, and other forms. Trenberth concluded that the challenge is to better determine the energy budget at the Earth's surface on a continuing basis. Such studies may provide critical information on ocean heat storage, ice-melts, changes in sea-surface temperature (SST), and atmospheric circulation.

**Bill Collins** (NCAR) gave an overview of NCAR climate modeling activities. Presently, the focus of model development at NCAR is the Community Climate System Model version-3 (CCSM-3) due to be released later this year. A diagnostic aerosol climatology based on assimilation of Advanced Very High Resolution Radiometer (AVHRR) data into a chemical transport model is now used to force SW fluxes. The latest model runs show aerosol SW forcing to be a  $6 \text{ W/m}^2$  decrease in surface insolation and a  $3 \text{ W/m}^2$  increase in atmospheric absorption. **Jeff Kiehl** (NCAR) presented an analysis of the sensitivity of evolving CCSM versions and compared them with those for the evolving Geophysical Fluid Dynamics Laboratory (GFDL) model. The sensitivity of the two models to a doubling of  $\text{CO}_2$  differed by a factor of two for earlier versions. As a result of changes to both models these differences were greatly reduced. Kiehl presented the results of a simulation for the past millennium which showed that the temperature response was proportional to the flux forcing.

**John Harries** (Imperial College, London) presented an overview of the GERB instrument, which is currently flying aboard the first Meteosat Second Generation (MSG-1) satellite. The instrument measures TOA radiative fluxes in two BB channels: a total channel (0.32-100.0  $\mu\text{m}$ ), and a SW channel (0.32-4.0  $\mu\text{m}$ ). The LW flux is obtained by subtraction. GERB data are processed in conjunction with data from the Spinning Enhanced Visible and Infrared Imager (SEVIRI). The GERB instrument produces TOA SW and LW fluxes with 10-km resolution every 15 minutes. The instrument is performing well overall. There are some minor problems with stray light affecting the detectors, and with geolocation they are being addressed.

#### Discussion on Comparison of Models and Observations

Bruce Wielicki and Bill Collins facilitated a discussion on testing climate models. Wielicki presented the observational perspective and Collins represented the modeling viewpoint. Wielicki showed several model and observation comparisons and posed several key comparison questions: What collection of tests might be sufficient? Is closure possible? If aliens gave us 10 climate models and said one was perfect: how would we know which one? Could we tell if they were lying? He then listed some key physical processes to stimulate the discussion. Bill Collins and Jeff Kiehl gave an overview of the status of climate modeling at NCAR and a roadmap for future development activities. David Randall (Colorado State University) suggested that, at a minimum, the models must be able to reproduce the forcing in agreement with observations. Kevin Trenberth, Tony Slingo (University of Reading, UK), and other NCAR

scientists also made key contributions to the discussions from the modeler's perspective. They acknowledged that we do not know what tests are needed to sufficiently validate the models and that the observational accuracy requirements are not well established, but all agreed that the continuation of accurate radiation-budget measurements was an essential element.

New directions include tests at a wide range of time and space scales — from weather prediction to decadal. Tests of cloud systems by cloud type is a new important method.

#### Investigator Presentation Highlights

**Robert Cess** (State University of New York at Stony Brook) presented a study in which satellite radiation measurements from ERBE and CERES during El Niño periods were used for testing the performance of the Hadley Centre climate model (HadAM3). Averages from HadAM3 for the period from 1961-1990 represented the average conditions. The January 1997 to August 1998 period was chosen to represent El Niño conditions. Analysis of ERBE and CERES data showed that cloud vertical structure swaps positions between the eastern and western Pacific during the 1997-98 El Niño. An examination of observational data showed a weakening of Walker circulation in the Pacific during 1997 and 1998. The HadAM3 results also indicated some weakening, but the differences between HadAM3 and CERES results were still large.

Takmeng Wong gave an update on the decadal changes of Earth radiation budget using altitude-corrected ERBE/ERBS nonscanner data. The effect of the ERBS altitude correction is to change the overall magnitude of the

reported decadal changes from 3.0 to 1.5  $\text{W}/\text{m}^2$  in the outgoing LW radiation (OLR) and from -2.8 to -3.5  $\text{W}/\text{m}^2$  in the reflected solar radiation. Wong also presented results from three recent long-term studies based on International Satellite Cloud Climatology Project (ISCCP) cloud data and National Centers for Environmental Prediction (NCEP) reanalysis data, surface cloud data, and ocean heat storage data. All the studies support the decadal changes shown in the ERBE/ERBS nonscanner record.

**Bing Lin** (LaRC) presented his work on the variations of tropical deep convective cloud (DCC) systems with rainfall and SST. He combined DCC data from CERES SW and LW measurements, cloud properties derived from NB VIRS visible and infrared measurements, and TRMM Microwave Imager (TMI) retrievals of precipitation into an integrated, collocated data set. Lin found that DCC rainfall rates and area coverage increase with SST. No evidence was found to support the hypothesis that an increase in precipitation would dehydrate convective systems and reduce the effective size of convective clusters. Instead, the effective sizes of the convective clusters were found to increase with increasing SST, in conflict with the Iris hypothesis.

Bill Collins reported on the status and proposed extensions of the NCAR aerosol assimilation effort. A chemical transport model in conjunction with aerosol deposition and scavenging data is assimilated with NCEP/NCAR reanalysis wind and meteorological fields to produce aerosol optical depth (AOD) fields. These are, in turn, constrained by satellite AOD observations from AVHRR or MODIS. He presented an analysis of radiative forcing derived

using community atmosphere model and assimilated aerosol products. Comparison with CERES data indicated large differences in absorption by dust aerosol. Collins proposed to resolve dust-absorption differences by examining dust optical properties from other sources, and to use new carbon-emission data in the assimilation.

Thomas Charlock presented an assessment of aerosol direct radiative forcing on TOA and surface SW and LW fluxes using CERES/SARB results. MATCH AODs combined with aerosol optical properties from other sources were used to evaluate the forcing in Terra Edition-2A data for 6 months of 2001 over about 40 ground sites of the Atmospheric Radiation Measurement (ARM), Baseline Surface Radiation Network (BSRN), and Surface Radiation (SURFRAD) networks. Forcing was computed for multiple combinations of surface albedo, cloud height, and cloud optical depth. Several sets of results for clear-sky and all-sky conditions were shown. Large forcing was found for both TOA and surface SW fluxes. Forcing on LW fluxes was significant only at the surface. Charlock concluded that SARB results present a viable method for estimating aerosol direct-radiative forcing.

**Anand Inamdar** (Scripps Institution of Oceanography) presented a validation of CERES-derived downward fluxes in the 8-12  $\mu\text{m}$  window at the ARM Southern Great Plains (SGP) central facility. Atmospheric Emitted Radiance Interferometer (AERI)-measured zenith radiance was converted to WN flux using the procedures of the Quality Measurements Experiment (QME) for the Terra period. For the TRMM period, a radiance-to-flux conversion scheme was developed in terms of column

precipitable water. Inamdar concluded that the bulk of the error in BB fluxes comes from the window region.

**Alexander Ignatov** (NOAA National Environmental Satellite, Data, and Information Service — NESDIS) examined the consistency between AODs derived using MODIS data from Terra and Aqua satellites. AODs reported in CERES/SSF come from AVHRR-type retrievals from 1 or 2 channels and also from MODIS-type multi-channel retrievals. AVHRR-type retrievals from Terra and Aqua agreed well with each other but MODIS-type retrievals showed significant differences. In general, Aqua results showed lower errors than Terra results. Ignatov also compared the two retrieval methods over 25 ocean locations for 2000-2003. AODs at 1.63  $\mu\text{m}$  showed good agreement at all locations. AODs at 0.64  $\mu\text{m}$  agreed well at open-ocean locations but were much higher at a high-altitude inland site (Aral sea) for AVHRR-type retrievals.

**Ellsworth Dutton** (NOAA Climate Monitoring and Diagnostics Laboratory, CMDL) reviewed the activities of the combined network of CMDL and SURFRAD ground sites that make surface-based radiometric and related measurements in support of CERES and other EOS projects. All of these sites are BSRN approved and contribute to BSRN databases. These sites routinely measure direct, diffuse, global, and upward solar radiation, as well as downward and upward infrared radiation. An effort to measure spectral AODs, which can be composited into site AOD climatologies, has been initiated. Cloud optical depths and nighttime sky cover are also produced.

**Xiquan Dong** (University of North Dakota) reported on the validation of CERES cloud properties derived from VIRS data for January 1998 – June 2001 using ground-based measurements from the ARM SGP central facility. Satellite-derived heights and temperatures for optically thick clouds showed good agreement for both day and night. Agreement for optically thin clouds was better during the day. Comparisons for thin cirrus clouds were good, and VIRS retrievals showed better agreement than MODIS retrievals.

**Lou Smith** (National Institute of Aerospace) presented a comparison of the diurnal variability of OLR in the Hadley Centre HadAM3 model with that in ERBS data. Principal-components (PC) analysis was used to compare diurnal cycle in the two data sets over the ERBS domain (55°N – 55°S) for July and the N.H. summer (Jun-Jul-Aug) averaged over 5 years. Comparisons were made separately for land and ocean regions. Results showed that PC-1 over land were very close in diurnal range. Model data showed substantial lag from solar heating during day and considerable cooling during night relative to ERBS data. Over oceans, ERBS data showed much greater variability and irregularity than model data.

**Roger Davies** (Jet Propulsion Laboratory) presented results from a study of regression relations between coincident Multiangle Imaging Spectroradiometer (MISR) spectral (NB) radiances with CERES BB SW radiances. The objectives of this study were to check MISR calibration relative to CERES, especially at low light levels, and to derive BB albedos at high spatial resolution using MISR radiances. Results showed that constrained single regressions provided the best calibration tests. Multiple

regressions provided the lowest rms differences and residuals for NB-BB albedo relations.

**Michel Viollier** (Laboratoire de Meteorologie Dynamique, France) presented a study in which Polarization and Directionality of Earth's Reflectances (POLDER) multi-directional measurements were combined with CERES BB measurements to validate a NB-BB conversion scheme and enhance ADM development. POLDER made spectral radiance measurements at multiple wavelengths and viewing directions. Analysis of June 2003 data showed that, relative to CERES, the POLDER radiances were underestimated by about 1% over oceans and about 2% over land.

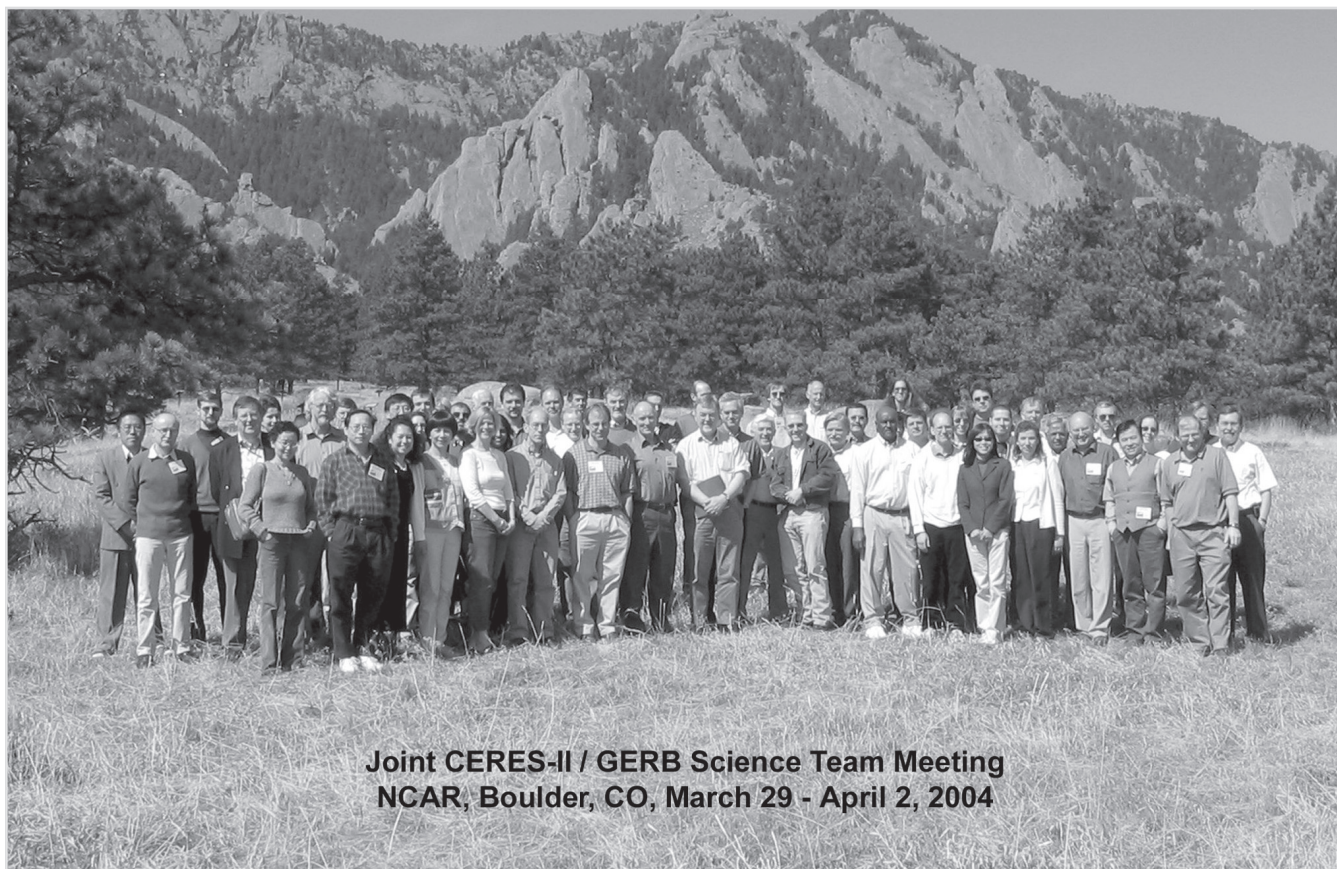
**Steven Dewitte** (Royal Meteorological Institute of Belgium) compared CERES

and GERB radiation budget parameters. The two systems complement each other because CERES viewing geometry provides better ADM information while GERB provides better temporal sampling. Comparisons of unfiltered SW radiances showed better agreement over desert regions than over cloudy scenes; LW comparisons showed good agreement for all scenes. Dewitte also showed a long time series of total-solar-irradiance measurements.

#### GERB Science Team Meeting

The 21st GIST Meeting, led by John Harries, focused on instrument status, calibration methods and status, instrument operations, validation, data processing and archiving, and data-product definitions. The CERES-II team shared lessons learned in ground calibration, in-flight calibration

validation, definition of clear-sky and monthly averaged products, flux validation, ADM use, data-release experience, and user support. A number of GERB-CERES intercomparison studies were discussed including surface-based validation efforts by Ernesto Lopez-Baza (U. Valencia, Spain). **Jacqui Russell** (Imperial College) presented the GERB data-release requirements, plan, and schedule. Early scientific analyses using the GERB and SEVERI data featured studies by Tony Slingo on the radiometric signature of Saharan dust, H. Brindley (Imperial College) on the radiative effects of aerosols, M. Viollier on time sampling, and Rainer Hollmann (Deutscher Wetterdienst, Germany) on surface radiation budget.



**Joint CERES-II / GERB Science Team Meeting  
NCAR, Boulder, CO, March 29 - April 2, 2004**



## Update on Recent ESSP Mission Activities

— Alan Ward, [alan\\_ward@ssaihq.com](mailto:alan_ward@ssaihq.com), Science Systems and Applications, Inc.

The following article provides an update on recent activities related to NASA's Earth System Science Pathfinder (ESSP) missions and also previews some upcoming activities. A component of NASA's Earth Science Enterprise (ESE), ESSP missions are intended to address unique, specific, highly-focused scientific issues and provide measurements required to support Earth system science research. As of today, the Gravity Recovery and Climate Experiment (GRACE) is the only ESSP mission that has been launched. However, in 2005, CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) will launch, and preparations for outreach and education activities are well underway. Three more missions are now proceeding with formulation and planned for launch by 2010: the

Orbiting Carbon Observatory (OCO), Aquarius, and the Hydrospheric State Mission (HYDROS).

### Update on GRACE

The GRACE mission celebrated two years in orbit on March 18 of this year. It continues to perform well and is bringing scientists the most detailed and accurate measurements of the Earth's gravity field that have ever been obtained. This information will be applied to a wide variety of practical applications in Earth system science and may have far-reaching benefits for society. To give a sense for how much new information GRACE is giving us, Principal Investigator (PI), Byron Tapley from the University of Texas Center for Space Research (UT-CSR) says that, "In just 30 days, GRACE exceeded the

information gained in over 30 years of previous study."

### GRACE Hydrology Workshop Held in March

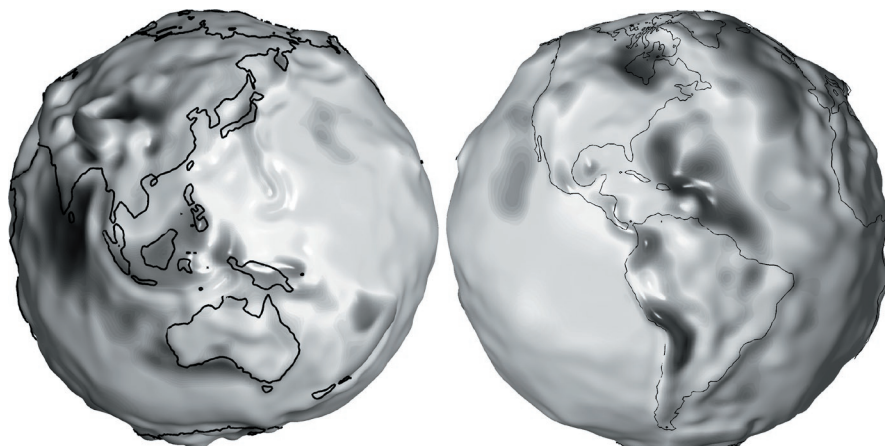
Members of the hydrology and geodesy communities gathered at the University of California at Irvine (UCI) on March 22. The workshop was organized by Jay Famiglietti (UCI) and was sponsored by the NASA Terrestrial Hydrology and Solid Earth and Natural Hazards programs. The workshop focused on four themes:

- Theme 1: Overview of the GRACE mission and its role in hydrology;
- Theme 2: Progress and current activities in hydrology;
- Theme 3: New applications and science using GRACE; and
- Theme 4: Observations and models for validation and comparison.

Participants at this meeting included Byron Tapley and GRACE Project Scientist, Michael Watkins (JPL), who also was also one of the speakers in Theme 1. For a complete workshop agenda and links to all of the Power Point presentations that were given go to [www.ess.uci.edu/~famiglietti/grace/](http://www.ess.uci.edu/~famiglietti/grace/)

### Joint CHAMP/GRACE Science Meeting Planned for July

Four years after the launch of GRACE's predecessor, the Challenging Minisatel-



These globes show the Earth's long-wavelength gravity field and are known as *gravity anomaly maps* because they illustrate by how much the Earth's actual gravity field departs from normal as defined by a simplified mathematical gravity model that assumes the Earth is perfectly smooth and featureless. The maps show that our home planet is restless and dynamic, both at its surface and deep within its interior. For more information on these images including full color graphics see: [eospsa.gsfc.nasa.gov/eos\\_homepage/for\\_educators/educational\\_publications.php](http://eospsa.gsfc.nasa.gov/eos_homepage/for_educators/educational_publications.php) Click on "GRACE: Studying Earth's Gravity from Space"

### CALIPSO's Lidar Undergoes Successful Atmospheric Testing in Colorado

The CALIPSO lidar known as Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP), underwent active laser testing in late 2003 at Ball Aerospace facilities in Boulder, Colo. Green laser beams pierced the night skies between December 7 and 11 and provided better-than-expected results. Testing was completed ahead of schedule. The tests involved atmospheric backscatter measurements performed from the ground and verified specific aspects of the lidar performance. NASA and Ball Aerospace officials said the success was due to the precision of the instrument suite, good weather conditions, and a well-prepared Langley test team.

Engineers placed the payload inside an environmentally controlled clean room with windows in the roof above the transmitter and the receiver, allowing the lidar to be operated outdoors. As CALIOP acquired data, a well-characterized laboratory lidar took backscatter data to provide supporting information. The atmospheric test is the first verification of the end-to-end performance of the lidar. It allowed for precise testing of some critical functions, such as the boresight search, align, and scan, that cannot be adequately tested at the subsystem level. Researchers also conducted an etalon temperature scan and a thermal stability test. In addition, the testing acquired characterization and baseline data that will be compared with the results

of the second test at Vandenberg Air Force Base in California just prior to launch.

lite Payload (CHAMP), and more than two years after successfully placing the GRACE satellite pair into orbit, a first *joint* meeting of the CHAMP and GRACE Science Teams will be held on July 6-8, 2004 at the GeoForschungsZentrum Potsdam (GFZ).

The meeting will include a broad discussion within the international science community on the exploitation and application of the gravimetric, magnetic, and atmospheric data products from these highly innovative missions in low-altitude orbits. It will also demonstrate the potential of using data from these two missions in combination with data from complementary remote-sensing missions, aircraft and ground instrumentation, to study various areas of interest in Earth system science.

### Update on GRACE Education/Public Outreach Activities

In December of 2003, an article entitled "Weighing Earth's Water from Space" was published on NASA's Earth Observatory website ([earthobservatory.nasa.gov/Study/WeighingWater/](http://earthobservatory.nasa.gov/Study/WeighingWater/)). The article highlights plans to use time-variable gravity maps that will soon be available to study water-storage change in aquifers from the vantage point of space. A shorter version of this story also appeared on the NASA Portal ([www.nasa.gov/vision/earth/lookingatearth/f\\_grace.html](http://www.nasa.gov/vision/earth/lookingatearth/f_grace.html)). In February 2004, an article entitled "Gravity's Rainbow" appeared in *National Geographic*. The article quotes Byron Tapley and highlights the gravity-anomaly maps shown in this article. Also, more

recently, an article entitled "Amazing GRACE" ([www.nasa.gov/missions/solarsystem/f\\_grace.html](http://www.nasa.gov/missions/solarsystem/f_grace.html)) was published on the Portal that gives a more general overview of the GRACE mission and includes a quote from GRACE Project Scientist, Mike Watkins (JPL).

An Education and Public Outreach team routinely meets to keep abreast of ongoing activities related to GRACE. Members are from UTCSSR, JPL, and Goddard. They attend various meetings and activities throughout the year and distribute information on the GRACE mission. Recently GRACE materials (including brochures, fact sheets, and lithos, CD ROMS, etc.) have been distributed at a wide variety of venues including the American Society for Curriculum Development (ASCD) meeting, the National Science Teachers Association (NSTA) meeting, the Aquarium of the Pacific, and even at a local science fair at an elementary school in California. Plans are in the works to distribute materials at the upcoming JPL Open House, May 15-16, and also at the Odyssey of the Mind World Finals at the University of Maryland, College Park, May 28-31. Thousands of students will be present for this event, and each year, NASA sponsors an Earth Science problem.

### CALIPSO Science Team Meeting Held in Williamsburg, VA

The CALIPSO Science Team held a meeting November 19-20, 2003 in Williamsburg, Va., to review the status of the mission and algorithm development. The main focus of the meeting was a detailed review of the CALIPSO algorithms and data-processing system. To a large degree, Level 1 lidar, Imaging Infrared Radiometer (IIR), and Wide-Field Camera (WFC) algorithms have

### **CALIPSO Payload Ready for Integration in France**

The CALIPSO payload was shipped to the Alcatel Space facility in Cannes, France, on February 10, where the U.S. and French payload will be integrated into a Proteus spacecraft platform. The payload successfully completed mechanical integration to the Proteus platform on March 1, and electrical integration is underway. An aliveness test in which the platform will be powered up occurred on March 12. Final testing and launch of the satellite will take place at Vandenberg Air Force Base. CALIPSO will share the Delta II rocket that will take it to orbit in a dual configuration with CloudSat. Presently, the official launch date is for late March 2005.

been completed and tested. Level 2 lidar algorithms are continuing to evolve with good progress being reported in all areas. Level 2 IIR algorithms also are approaching maturity. Initial versions of all Level 2 algorithms have been coded and tested. The team has scheduled major tests for this spring and summer. A benchmark analysis of the CALIPSO data-processing system for present Level 1 and Level 2 code builds showed adequate processing reserves for expected requirements.

The team also reviewed validation plans and noted that Langley's High Spectral Resolution Lidar (HSRL) is under assembly. Scientists plan to fly the instrument during the Intercontinental Chemical Transport Experiment - North America (INTEX-NA) mission this summer to verify its performance before CALIPSO validation activities. The CALIPSO and CloudSat teams

continue to seek collaboration activities with other field missions.

A report on the payload status indicated the team had installed all components of the lidar and completed final payload environmental testing in preparation for atmospheric testing at Ball Aerospace & Technologies Corporation. Fortunately, the CloudSat "cup napping" incident was resolved when the CloudSat Principal Investigator (PI) and Deputy PI met CALIPSO's ransom demands and arrived at the meeting wearing Hawaiian shirts. The next CALIPSO Science Team meeting will be hosted by the Centre National d'Etudes Spatiales (CNES) and is scheduled for May 3-5 in Nice, France, near the Alcatel facility, where the payload is undergoing satellite integration. In addition, a joint CALIPSO/CloudSat meeting is planned for Fall 2004.

### **CloudSat Science Team Meeting Coming Up in May**

A CloudSat Science Team meeting is planned for May 24-27, 2004 in Laguna Beach, CA. Look for a review of this meeting in our May/June issue of *The Earth Observer*.

#### *Planned Education and Public Outreach Activities for CALIPSO/CloudSat*

CloudSat and CALIPSO will be launched on the same Delta II launch vehicle in 2005. Therefore, the missions are working together on several education and public-outreach activities. In addition, each mission has some independent activities planned as well.

#### *Teachers to Learn About the A-Train*

The CALIPSO and CloudSat outreach teams are partnering with the Aura

mission, and with the GLOBE program, to provide two educator workshops during the summers of 2004 and 2005. The three missions mentioned will all be part of the Afternoon Constellation of satellites known colloquially as the A-Train, and are thus working together on this effort. The workshop title is: NASA Satellites Study Earth's Atmosphere: CALIPSO, CloudSat and Aura working with the GLOBE Program. The first workshop is planned for July 12-22 at Colorado State University, in Fort Collins Colorado. The second workshop will be conducted during the summer of 2005 at Hampton University in Hampton Virginia. The workshops will primarily target middle-school educators and science supervisors who will work with the CALIPSO, CloudSat, and Aura missions to involve students in reporting visual cloud observations and aerosol data taken with a sun photometer. All data will be reported at the GLOBE website. Teachers from across the United States will be selected to participate. Accepted participants will receive support to develop and implement a regional workshop in their local school systems.

#### *The CloudSat Education Network*

This network will provide the opportunity for schools to partner with the CloudSat Science and Education Teams. The Network will use proven science and education programs, to partner scientists, teachers, students, and the communities where they live to give students meaningful, authentic and contemporary high-quality educational experiences. Student activities and learning outcomes designed within the program have been chosen to meet both general education outcomes and specific standards or objectives from local school curricula. The main focus of

the knowledge-development component of the project is to help students better understand long-term climate change and the climatic processes that maintain the Earth's energy balance.

Launch of the CloudSat satellite is scheduled for June 17, 2005, and the CloudSat Education Network will begin supporting the Science mission beginning midyear 2004 and continue through early 2007. Participation in the network throughout the duration of the project will be monitored, and schools will need to maintain levels of participation in order to maintain "Membership" in the network. The base level of participation is the reporting of environmental data identified in the project every 16 days coinciding with the CloudSat satellite overpass. The data requested will include cloud cover, cloud type, temperature, and precipitation.

The first NASA CloudSat Education Network Training was held in Darwin, Australia on February 10 and 11, 2004. The CloudSat Education Network Training team, Jennifer Lockett (Coordinator of Education and Outreach) and John Lockley (GLOBE NZ and University of Waikato), trained teachers from 10 schools across the Northern Territory. A significant feature of the Teacher-Training workshop was the development of curriculum implementation strategies to align the educational opportunities offered by the CloudSat Education Network to the Northern Territory Curriculum Framework, especially in the Learning Areas of: Science, Math, Society, and Environmental Learning, and Learning Technology. In addition, they introduced the Network to others by speaking with over 20 teachers and 450 students. The Network will be limited to 100-150

schools worldwide. Currently, schools from Australia, New Zealand, Ghana, Cameroon, Croatia, Germany, and the U.S. are prepared to participate. The network is pursuing existing and new contacts in Thailand, Taiwan, South Africa, the United Kingdom, Japan, and Pakistan. Schools have been targeted through existing networks and contacts are being made in Russia, Iceland, Sweden, Finland, Estonia, Canada, and China.

#### *"The A-Train Express" Set to Air May 20*

The CALIPSO and CloudSat outreach programs are partnering with NASA CONNECT to produce a show titled *The A-Train Express*. In the show students will learn how weather affects their daily lives and just what the difference is between weather and climate. The students will also be introduced to two of NASA's Earth-science satellite missions CALIPSO and CloudSat. These missions will soon be joining the A-Train. CALIPSO and CloudSat will use remote-sensing instruments that are unique to their missions for data collection. CloudSat will use radar and provide a global survey of cloud properties to aid with improving cloud models and the accuracy of weather forecasts. CALIPSO will use lidar to detect size and distribution of aerosols to improve our understanding of the role aerosols and clouds play in Earth's climate system.

During the show, the students will see how national and international scientists are using satellite technology to help improve weather forecasting to give us a better understanding of clouds and aerosols and how they affect climate change. In addition, students watching the show will see other students from the United States

and France performing inquiry-based activities and using a sun photometer to collect aerosol data for CALIPSO and the GLOBE program. These activities have been carefully developed to assist students with making connections between NASA research and the mathematics, science, and technology they learn in their classrooms. The program will air Thursday, May 20, 2004. Related Website: [connect.larc.nasa.gov/episodes.html](http://connect.larc.nasa.gov/episodes.html)

#### *Problem-Based Learning Module Planned for CALIPSO Website*

The CALIPSO outreach team is currently collaborating with the Consortium for Problem-Based Learning (PBL) to develop an online PBL module for the CALIPSO outreach website. The module, which will primarily target middle-school students, will also be made available to museums and science centers for stand-alone computers. The module incorporates use of an interactive sun photometer created with flash animation.

#### *Instructional Video on Using a Sun Photometer*

The CALIPSO outreach team recently collaborated with the WHRO Public Broadcasting Network to produce a video on how to use the CALIPSO/GLOBE sun photometer. The video gives background information on what aerosols are and demonstrates step-by-step how to use a sun photometer to measure the aerosol optical thickness (AOT) of the atmosphere.

#### *Interactive Website Activities Related to CALIPSO*

The CALIPSO outreach team continues to expand the Atmospheric Arcade

portion of the CALIPSO outreach website. The purpose of the arcade is to provide interactive learning activities for students and the general public that offer atmospheric science instruction demonstrated in a fun manner. Teachers are also encouraged to utilize the Atmospheric Arcade activities in their lessons about climate change and the atmosphere. Currently the Atmospheric Arcade houses activities and games such as: The Light Spectrum, Layers of the Atmosphere, the Greenhouse Effect, Changes in Optical Depth, Cloud Match Game, Atmospheric Trivia game, Atmospheric Crossword Puzzle, and an interactive book titled "Atmospheric Aerosols: An Interactive Guide to Discovery".

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CALIPSO Outreach Contacts: Dianne Q. Robinson, CALIPSO Outreach Director, Hampton University [dianne.robinson@hamptonu.edu](mailto:dianne.robinson@hamptonu.edu)  
Barbara H. Maggi, CALIPSO Assistant Outreach Director, Hampton University [Barbara.maggi@hamptonu.edu](mailto:Barbara.maggi@hamptonu.edu). For more information click on "OUTREACH" at [www-calipso.larc.nasa.gov/](http://www-calipso.larc.nasa.gov/)

### **NASA Gives Three Newest ESSP Missions Green Light to Continue Mission Formulation**

Taken from NASA Headquarters/JPL Press Release from January 6, 2004

In December of 2003 NASA authorized all three of the missions that were chosen in the most recent round of ESSP selections to proceed with mission formulation. These were OCO, Aquarius, and HYDROS. Each mission

performs a first-of-a-kind exploratory measurement that will help answer fundamental questions about how our planet works and how it may change in the future. OCO will enhance our understanding of Earth's carbon cycle and climate. Aquarius will examine the way oceans affect and respond to climate change. HYDROS will study how water, energy, and carbon are exchanged between land and Earth's atmosphere.

"These three innovative missions have demonstrated they are ready to use state-of-the-art remote-sensing technology to observe and help us understand the cycles of water, energy and carbon through Earth's system. These are essential ingredients for sustaining life on Earth, and NASA is using the power of space technology to understand them," said Ghassem Asrar, NASA's Associate Administrator for Earth Science. "NASA plans to negotiate contract awards for these low-cost missions that address key scientific questions regarding how Earth's atmosphere, oceans and land work together to shape our weather, climate and environment," he said.

#### *Orbiting Carbon Observatory*

OCO's two-year mission is targeted for launch in August 2007. It will provide the first global, space-based measurements of atmospheric carbon dioxide. The measurements will have the precision to identify and monitor human and natural processes responsible for absorbing and emitting this important greenhouse gas, a fundamental building block for food, fiber, and life on Earth.

Precise ground-based measurements, collected since the 1970s, indicate only about half of the carbon dioxide

emitted into the atmosphere by fossil-fuel combustion has remained there. The land and oceans have apparently absorbed the rest. However, ground-based measurements are not adequate to determine how or where this absorption is occurring. These uncertainties compromise our ability to predict future atmospheric carbon-dioxide concentrations or their effect on the climate system.

David Crisp of NASA's Jet Propulsion Laboratory, Pasadena, Calif., is principal investigator for the mission, which includes more than 19 universities, corporate and international partners.

#### *Aquarius*

Aquarius's three-year mission, targeted for launch in September 2008, is the first satellite mission specifically designed to provide monthly global maps of how salt concentration varies on the ocean surface. Variations in ocean-surface salinity are a key area of scientific uncertainty. Scientists wish to better understand how these variations modify the interaction between ocean circulation and the global water cycle, which, in turn, affects the oceans' capacity to store and transport heat and regulate Earth's climate. The mission seeks to determine how the ocean responds to the combined effects of evaporation, precipitation, ice melt, and river runoff on seasonal and inter-annual time scales, and their impact on the global distribution and availability of fresh water.

Gary Lagerloef of Seattle's Earth and Space Research is the principal investigator. More than 17 universities, corporate, and international partners will be involved in the mission, including Argentina's Comision Nacional

de Actividades Espaciales. NASA will provide the Aquarius salinity sensor, project management, launch services, and science data processing. Argentina will provide the spacecraft, additional instruments and mission operations.

#### HYDROS

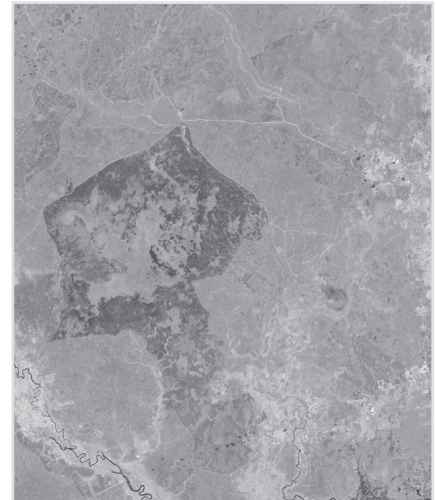
HYDROS will make unprecedented measurements of Earth's changing soil moisture and the freeze/thaw status of land surface that, together, define the state of Earth's hydrosphere. This state links the water, energy, and carbon cycles over land. HYDROS measurements will open new frontiers in our understanding of how these global cycles work together in the Earth system. Numerical models used for day-to-day weather prediction need soil-moisture estimates as initial conditions for forecasts. Incorporating

real observations into these models will significantly improve forecast accuracy. Soil moisture is among the top terrestrial environment measurement requirements of the Departments of Defense and Transportation because of the impact on land navigation and aviation weather.

Contributing partners for the HYDROS mission, in addition to NASA, include the Canadian Space Agency and the Department of Defense. The HYDROS science team draws from several universities, NASA centers, and research and operational branches of federal agencies. The principal investigator is Dara Entekhabi of the Massachusetts Institute of Technology, Cambridge, Mass.



This image from April 16 shows the large area burned by East Fork fire, which occurred in mid-April, 2004 in the Apalachicola National Forest in Western Florida. It appears as dark ring-shaped patch at the left side of the scene. Vegetation appears gray. The scene was captured by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on the Terra satellite. Image courtesy NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team



## Landsat 7 Celebrates Its 5<sup>th</sup> Anniversary

On April 15, Landsat 7 celebrated five years on orbit. During the 5 years, it racked up the following statistics:

- 405,000 images for the U.S. archive;
- imaged the U.S. 106 times;
- acquired 505,400 images for International Cooperators;
- furnished image data to 30 distinct ground stations on behalf of the International Cooperators, and
- Enhanced Thematic Mapper Plus (ETM+) produced 339 Terabytes of land imaging data.

Over the five years, the team received numerous awards including the William T. Pecora Award, Aviation Week and Space Technology Laurel Award, and both the Goddard Space Flight Center and NASA Award for Government-Industry Partnership.

Landsat 7 continues to be a useful source of land-mass observations. It has been a major contributor to the 30-year record of Landsat data-acquisition continuity. It continues to provide global observations of the planet, and systems are under development to expand the utility of the data.

Our hats are off to the Landsat Team for its outstanding success.

(Information furnished by the U.S. Geological Survey and Goddard Space Flight Center.)

## LP DAAC Release of MODIS Swath Reprojection Tool (MRTSwath) Software

— John Dwyer, [dwyer@usgs.gov](mailto:dwyer@usgs.gov), USGS

The Land Processes DAAC is pleased to announce the release of the MODIS Swath Reprojection Tool (MRTSwath)

The MODIS Swath Reprojection Tool (MRTSwath) provides the capability to transform MODIS Level-1B and Level-2 land products from HDF-EOS-swath format to a uniformly gridded image that is geographically referenced according to user-specified projection and resampling parameters. Correction for oversampling between scans as a function of increasing (off-nadir) scan angle is performed (correction for bow-tie effect).

Any of the input HDF-EOS Science Data Sets (SDSs) may be selected for processing, and a spatial subset can be defined by a rectangular subset of the input data. The subset area is defined

by the upper-left and lower-right corners expressed as input latitude and longitude, input line and sample pairs, or output projection coordinates.

During reprojection, the data may be resampled using the nearest neighbor, bilinear, or cubic-convolution methods. Datum conversions are not supported by the MRTSwath. Format options for output files include HDF-EOS, GeoTIFF, and generic binary. The MRTSwath is executed through a command-line interface.

MODIS Level-1B data are processed and distributed by the Goddard Earth Sciences Distributed Active Archive Center (GES DAAC) and by MODIS Direct Readout stations. The MODIS Level-2 land products are distributed by the Land Processes Distributed Ac-

tive Archive Center (LP DAAC) located at the USGS EROS Data Center.

The MODIS Swath Reprojection Tool is available to all registered users. This software will undergo further enhancements to correct problems that are identified, incorporate new functionality, and be modified to improve computational performance. The funding support for this work comes from the NASA Earth Science Data and Information Systems (ESDIS) Project. There are no restrictions on the use or redistribution of this software.



### *Kudos*

James D. Spinhirne, Code 912, Goddard Space Flight Center and a member of the GLAS Team and Co-Investigator on the CloudSat mission, was recently selected as one of 25 laureates for The Tech Museum Awards: Technology Benefiting Humanity. Spinhirne's Micro Pulse Lidar (MPL) was one of five finalists out of 96 nominations in the "Environment" category. MPL is a ground-based lidar system that enables autonomous monitoring of atmospheric clouds and aerosol scattering. It is an eye-safe, small, simple, reliable, long-range system that operates unattended and is significantly enhancing atmospheric research.

The *Earth Observer* staff and the entire scientific community congratulate James on this outstanding accomplishment.

## Earth Science Enterprise Education Program Update

—Ming-Ying Wei, [ming-ying.wei-1@nasa.gov](mailto:ming-ying.wei-1@nasa.gov), NASA Headquarters

—Diane Schweizer, [diane.schweizer@nasa.gov](mailto:diane.schweizer@nasa.gov), NASA Headquarters

—Theresa Schwerin, [theresa\\_schwerin@strategies.org](mailto:theresa_schwerin@strategies.org), Institute for Global Environmental Strategies

### Virginia Space Grant Consortium Awarded NASA Funding for Virginia Geospatial Extension Program

Applying space-age data to practical uses in Virginia is getting easier thanks to the Virginia Geospatial Extension Program at Virginia Tech. The program, which is sponsored by the Virginia Space Grant Consortium (VSGC) and Virginia Cooperative Extension, has just received its second Space Grant Workforce Development Award of \$100,000 from NASA's Office of Education. The award allows the partners to build on the already successful program established in July 2003.

The Virginia Geospatial Extension Program at Virginia Tech encourages and develops resources to foster geospatial workforce and career development. It offers a vision of how geospatial data and tools can improve resource management and yield economic and social benefits. Through targeted programs, it provides a direct avenue to promote geospatial tools and applications, and to integrate geospatial concepts throughout the K-20 educational pipeline.

Part of NASA's National Space Grant College and Fellowship Program, the Virginia Space Grant Consortium is a coalition of Virginia universities, NASA centers, state agencies, and other organizations with an interest in science and technology education and research. For

additional information, contact the Virginia Geospatial Extension Program at [jmcg@vt.edu](mailto:jmcg@vt.edu) or visit the program's Web site at [www.cnr.vt.edu/gep](http://www.cnr.vt.edu/gep). For more information on the Virginia Space Grant Consortium, visit [www.vsgc.odu.edu](http://www.vsgc.odu.edu) or contact Sharon Waters, (757) 766-5210, [scwaters@odu.edu](mailto:scwaters@odu.edu) or Lynn Davis, (540) 231-6157, [davisl@vt.edu](mailto:davisl@vt.edu),

### NASA Forms Education Advisory Committee

On February 21 and 22, NASA convened the first meeting of its new Education Advisory Committee at the agency's Washington Headquarters. The two-day session drew on the expertise of committee members, who will provide advice and recommendations to NASA's Associate Administrator for Education on education priorities and implementation strategies. The committee is chaired by William Harvey, Vice President, American Council on Education. A list of the committee members is at: [www.nasa.gov/home/hqnews/2004/feb/HQ\\_n04029\\_ed\\_advisory.html](http://www.nasa.gov/home/hqnews/2004/feb/HQ_n04029_ed_advisory.html).

### Dr. Bernice Alston Joins NASA's Education Enterprise

Bernice Pinkney Alston is the new Director of the Division of Elementary and Secondary Education at NASA Headquarters in Washington, DC. She

has a Bachelor of Science in Speech Pathology, a Master of Science in Communication Sciences, and an Educational Doctorate in Education Administration and Policy Management from George Washington University.

Alston comes to NASA from the Fund for Educational Excellence in Baltimore, MD. She was Director of Achievement First, a whole-school-change initiative that focuses on literacy. Alston has also been a teacher, principal, Director of the Speech and Hearing Clinic at Howard University, university professor, assistant superintendent, and a key player in systemic school reform. She has shared her knowledge of urban school reform with numerous school districts throughout the country.

### Pilot Test of NASA's New Astro-Venture Website for Grades 5-8

Middle school teachers can help pilot-test a NASA award-winning educational multimedia program that addresses basics of astronomy, geology, biology, and atmospheric science. Astro-Venture is an educational, interactive, multimedia Web environment where students use scientific inquiry while they search for and then build a habitable planet. Teachers can use online lesson plans and stimulating educational multimedia, and will receive gift packs of NASA certificates, CDs, posters, and more for participating. For more information and to register, visit



[astroventure.arc.nasa.gov/avpilot/](http://astroventure.arc.nasa.gov/avpilot/).

For the latest NASA Earth Science Enterprise news, visit the NASA Earth Observatory, [earthobservatory.nasa.gov](http://earthobservatory.nasa.gov), or [Science@NASA](mailto:Science@NASA), [science.nasa.gov](http://science.nasa.gov).



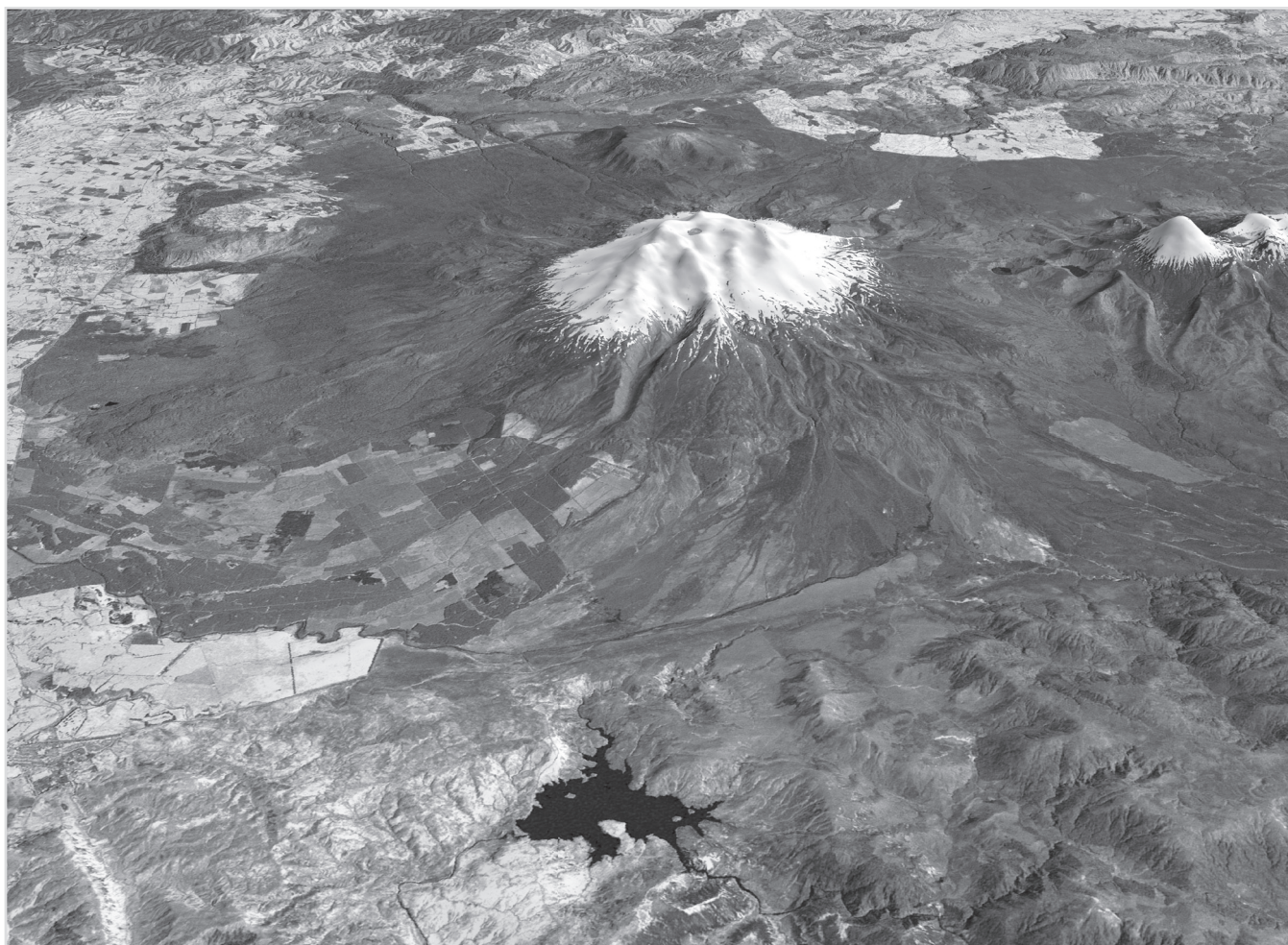
All around the world, people live in places where the threat of natural disaster is high. On the North Island of New Zealand, the Mount Ruapehu volcano is just such a threat. A towering, active stratovolcano (the classic cone-shaped volcano), snow-capped Ruapehu Volcano is pictured in this enhanced-color image. The image is made from topography data collected by the Shuttle Radar Topography Mission aboard the Space Shuttle Endeavour, launched on February 11, 2000, and imagery collected by the Landsat satellite on October 23, 2002.

Ruapehu is one of New Zealand's most active volcanoes, with ten eruptions since 1861. The eruptions aren't the only threat from the volcano, however. Among the most serious threats is a volcanic mudflow called a lahar. In between eruptions, a lake forms in the volcano's caldera from melting snow. If a previous eruption has deposited a dam of ash, rocks and mud in the lake's natural overflow point, then the lake becomes dangerously full, held back only by the temporary dam. In this scene, the lake is nestled among the ridges at the top of the volcano.

Eventually, the dam gives way and a massive flow of mud and debris churns down the mountain toward farmland and towns below. Scientists estimate that Ruapehu has experienced 60 lahars in the last 150 years. A devastating lahar in 1953 killed more than 150 people, who died when a passenger train plunged into a ravine when a railroad bridge was taken out by the lahar. The flank of the volcano below the lake is deeply carved by the path of previous lahars; the gouge can be seen just left of image center.

Currently scientists in the region are predicting that the lake will overflow in a lahar sometime in the next year. There is great controversy about how to deal with the threat. News reports from the region indicate that the government is planning to invest in a high-tech warning system that will alert those who might be affected well in advance of any catastrophic release. Others feel that the government should combat the threat through engineering at the top of the mountain, for example, by undertaking a controlled release of the lake.

Landsat data provided courtesy of the University of Maryland Global Land Cover Facility  
Landsat processing by Laura Rocchio, Landsat Project Science Office  
SRTM 3-arcsecond elevation data courtesy of SRTM Team NASA/JPL/NIMA  
Visualization created by Earth Observatory staff.



# Terrestrial Carbon Sinks Predicted from MODIS Satellite Data and Ecosystem Modeling

— Christopher Potter, *cpotter@mail.arc.nasa.gov*, NASA Ames Research Center

— Steven Klooster, *California State University*

— Ranga Myneni, *Boston University*

— Vanessa Genovese, *California State University*

## Introduction

The launch of NASA's Terra satellite platform in 1999 with the moderate resolution imaging spectroradiometer (MODIS) instrument on-board initiated a new era in remote sensing of the Earth system with promising implications for carbon cycle research. Direct input of satellite vegetation index "greenness" data from the MODIS sensor into ecosystem simulation models can be used to estimate spatial variability in monthly net primary production (NPP), biomass accumulation, and litter fall inputs to soil carbon pools. Global NPP of vegetation can be predicted using the relationship between leaf reflectance properties and the fraction of absorption of photosynthetically active radiation (FPAR), assuming that net conversion efficiencies of PAR to plant carbon can be approximated for different ecosystems or are nearly constant across all ecosystems.

The operational MODIS algorithm for FPAR can use up to seven atmosphere-corrected factors for spectral bi-directional reflectance functions (BRDFs) to compute the most probable values over the global land surface. The theoretical basis of the MODIS FPAR algorithm is given in Knyazikhin et al. (1998) and the implementation aspects are discussed in Knyazikhin et al. (1999). The MODIS FPAR algorithm is

BRDF-parameterized in terms of basic components of the energy conservation law, namely, canopy transmittance and absorbance (whose spectral variation can be explicitly expressed via the leaf spectrum) and two canopy structure specific wavelength-independent variables. This allows the algorithm to admit only those FPAR values for which the modeled BRDFs agree with the energy conservation law at the reflected wavelength of solar spectrum, thus allowing a significant reduction in the number of retrieved solutions. Extensive prototyping of the algorithm with data from different sensors (AVHRR, Landsat, SeaWiFS) has indicated that this constraint significantly enhances the accuracy of FPAR retrievals (Myneni et al., 2002).

A recent version of the CASA (Carnegie Ames Stanford Approach) model predicts terrestrial ecosystem fluxes using MODIS inputs at a geographic resolution of 0.5° latitude/longitude to infer variability in biosphere carbon fluxes. This model developed at NASA Ames Research Center is designed to estimate monthly patterns in carbon fixation, plant biomass increments, nutrient allocation, litter fall, soil carbon, CO<sub>2</sub> exchange, and soil nutrient mineralization. Early results from the NASA-CASA simulation study driven by global MODIS observations imply that above-average global temperatures in

2001 were associated with an increasing trend in terrestrial ecosystem sinks for atmospheric CO<sub>2</sub>.

As documented in Potter (1999), the monthly NPP flux, defined as net fixation of CO<sub>2</sub> by vegetation, is computed in NASA-CASA on the basis of light-use efficiency (LUE). Monthly production of plant biomass is estimated as a product of time-varying surface solar irradiance,  $S_r$ , and FPAR from the satellite AVHRR, plus a constant LUE term ( $e_{max}$ ) that is modified by time-varying stress scalar terms for temperature (T) and moisture (W) effects

Based on plant production as the primary carbon and nitrogen cycling source, the NASA-CASA model is designed to couple daily and seasonal patterns in soil nutrient mineralization and soil heterotrophic respiration (Rh) of CO<sub>2</sub> from soils worldwide. Net ecosystem production (NEP) can be computed as NPP minus Rh fluxes, excluding the effects of small-scale fires and other localized disturbances or vegetation regrowth patterns on carbon fluxes. Monthly mean surface air surface temperature (TEMP) and precipitation (PREC) totals for 1999-2001 come from NCEP reanalysis products (Kistler et al., 2001).

Continuity between AVHRR and MODIS sensor data for FPAR inputs to

NASA-CASA is an issue that must be addressed by recalibration of annual NPP model predictions from 2001 MODIS FPAR inputs with the same set of field measurements of NPP. To best match of predictions with previously measured NPP estimates at the global scale, the model bias term for 2001 MODIS FPAR inputs was reset to 0.34 g C MJ<sup>-1</sup> PAR, a value that is globally 11.5% lower than previously used in the model for AVHRR-driven NPP predictions from 1982-1998 (Potter et al., 2003).

It is worth noting from the MODIS calibration that low NPP sites tend to be overestimated by the 2001 MODIS FPAR data inputs to CASA's NPP predictions. This could be a result of comparing observed NPP that was measured 10 years or more before the predicted NPP in 2001, particularly if low NPP sites have been regrowing from disturbance and because recent climatic changes may have enhanced plant growth in northern mid-latitudes and high latitudes (Nemani et al., 2003).

#### Model Results for Terrestrial Carbon Fluxes

Predicted terrestrial NPP for the globe in 2001 was estimated at 52.6 Pg C (1 Pg = 10<sup>15</sup> g), which is slightly higher than the previous NPP range of between 45 and 51 Pg C per year for 1982-1998 (Potter et al., 2003). The time series of NASA-CASA's predicted NPP from 1982 to 2001 shows no major discontinuities. There is, nevertheless, a marked upward trend predicted in most zonal regions beginning in the early 1990s. This is consistent with the NPP modeling results over the time period of 1982-1999 from the NASA MODIS science team (Nemani et al., 2003).

Our NASA-CASA model result for NEP in 2001 reflects observed climate trends (WMO, 2001) between and within major continental areas of the terrestrial biosphere. In a study of 17 years of NASA-CASA results, Potter et al. (2003) demonstrated that temperature warming events are significantly associated with positive NEP (net sink fluxes) in high latitude tundra, grasslands, and boreal forest areas, whereas major drought events are significantly associated with negative NEP (net source fluxes) in tropical evergreen forests, temperate deciduous forests, croplands, grasslands, and savannas worldwide. Similarly in 2001, above average temperatures correspond to strongly positive NEP (net sink fluxes) across the high latitude zones of eastern Canada and Eurasia. Strongly positive NEP fluxes were also associated with the heavy rainfall reported in eastern Europe, Siberia, Australia, West Africa, and southern Africa. Strongly negative NEP fluxes were associated with droughts reported in south Asia, eastern Africa, northern China, and northern and eastern coastal South America.

Using MODIS land products, we have begun to identify numerous relatively small-scale patterns throughout the world where terrestrial carbon fluxes may vary between net annual sources and sinks from one year to the next. Predictions of NEP for these areas of high interannual variability will require further validation of carbon model estimates, with a focus on both flux algorithm mechanisms and potential scaling errors to the regional level.

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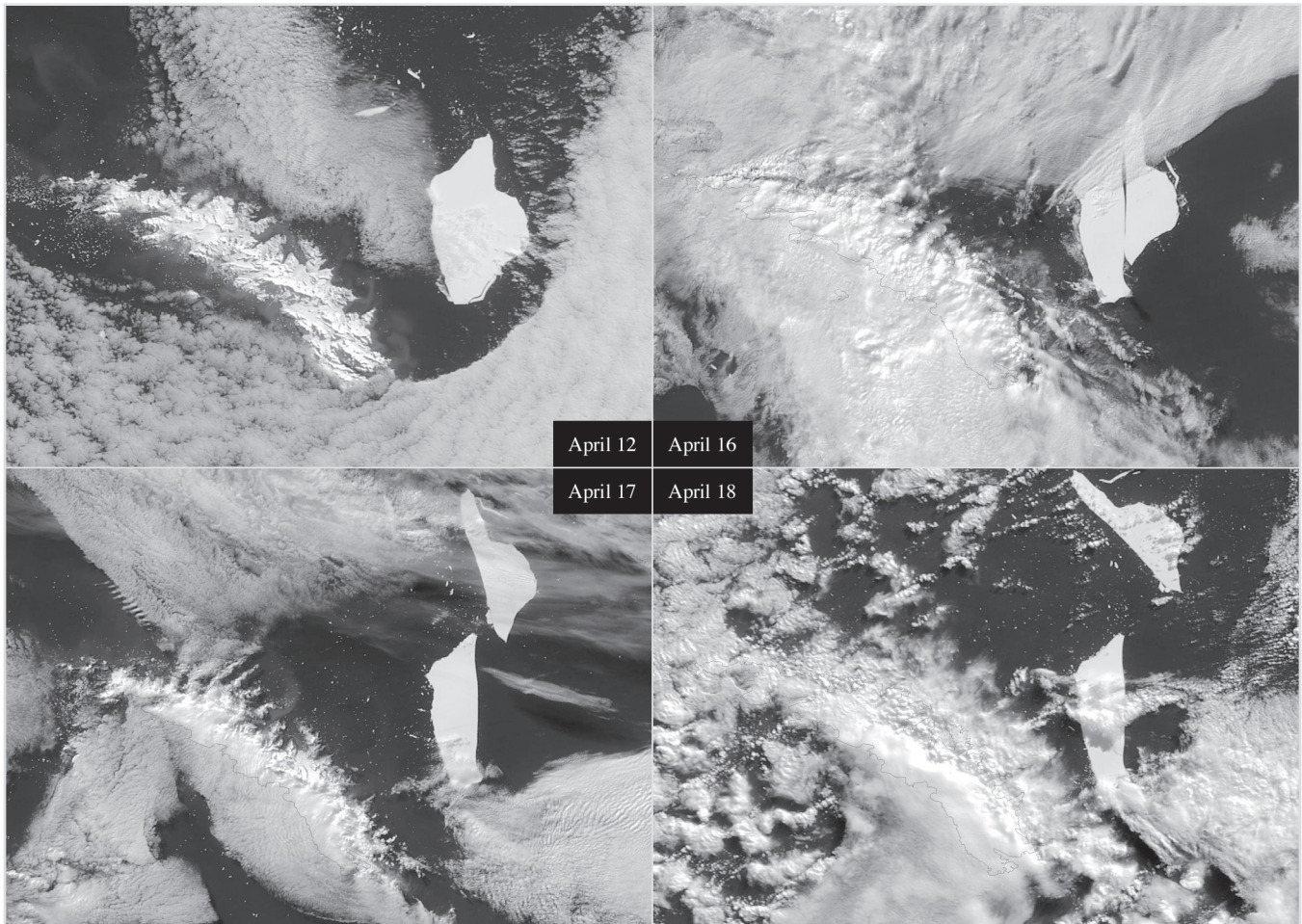
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Between April 12 and April 15, the A38-B iceberg split in half. The split was recorded in this series of Moderate Resolution Imaging Spectroradiometer (MODIS) images. On April 12, 2004, top left, the A-38B iceberg was about 25 nautical miles long. The next time MODIS flew over the iceberg on April 15, top right, A-38B had broken in half. By April 17, lower left, and April 18, lower right, the eastern half of the iceberg had moved quickly north and turned west. Image courtesy Jeff Schmaltz, MODIS Land Rapid Response Team at NASA GSFC





**Satellites Record Weakening North Atlantic Current**, Apr. 15; *MS-NBC, Scripps Howard News Service, U.K. Telegraph*; A North Atlantic Ocean circulation system weakened considerably in the late 1990s, compared to the 1970s and 1980s, according to **Sirpa Hakkinen** (NASA GSFC) and **Peter Rhines** (U. Washington).

Educational Segments on *KABC7 TV 6pm News*, Los Angeles, CA; "How Much Water Does the Large Ponderosa Pine Trees Use Every Day? Answer: ~300 Gallons/Day" and "The PDO and Drought."

Apr. 9, 16; *KABC-7* (a Los Angeles Television station); **Bill Patzert** (NASA JPL) provided weather anchor Dallas Raines, answers to educational television weather segments.

**NASA's Aura Satellite Delivered to Launch Site**, Apr.5; *Science Daily*; NASA's Aura spacecraft, the latest in the EOS series, arrived at Vandenberg Air Force Base, Calif., according to **Rick Pickering** (NASA GSFC) to begin launch preparations.

**NASA, French Team on New Satellite**; March and April; *Newport News Daily Press, Virginian Pilot*; **David Winker** (NASA Langley) and **Patrick McCormick** (Hampton University) discussed

the CALIPSO satellite and the future of climate science.

**NASA Uses a 'Sleuth' to Predict Urban Land Use**; Mar. 25; *Science Daily*; **Claire Jantz** and **Scott Goetz**, (Univ. of Maryland, College Park, Md., and the Woods Hole Research Center) using a USGS computer model called SLEUTH, found that developed land in the greater Washington-Baltimore metro area will likely increase by 80 percent by 2030.

**Land Cover Changes Affect U.S. Summer Climate**; Mar. 24; *Science Daily*; While climate may be impacted by carbon dioxide emissions, aerosols and other factors, a new study offers further evidence land surface changes may also play a significant role. Authors included **Somnath Baidya Roy**, (Princeton Univ.), **George Hurtt** (Univ. New Hampshire), **Christopher Weaver**, (Rutgers) and **Stephen Pacala** (Princeton).

**NASA Explains "Dust Bowl" Drought**; Mar. 18; *Associated Press, CBS, ABC, CNN*, and more worldwide coverage; **Siegfried Schubert** (NASA GSFC) and other NASA scientists including: **Max J. Suarez**, **Philip J. Pegion**, **Randal D. Koster**, and **Julio T. Bacmeister** have an explanation for one of the worst climatic events in the

history of the United States, the "Dust Bowl" drought, which devastated the Great Plains and all but dried up an already depressed American economy in the 1930s.

**Forest Dwellers Still Under High Fire Risk**; Mar. 17; *San Bernardino County Sun, Knight-Ridder News Service, The Miami Herald*; **Bill Patzert** (NASA JPL) was quoted in this article about last year's big fires in San Bernadino, California and said the region should expect drought-like conditions to continue for the next several years.

**Satellite Finds Warming "Relative" To Humidity**; Mar. 15; *Associated Press, Albuquerque Journal, LA Times, NY Newsday*; A NASA-funded study found some climate models might be overestimating the amount of water vapor entering the atmosphere as the Earth warms. **Ken Minschwaner** (New Mexico Institute of Mining and Technology) and **Andrew Dessler**, (Univ. of Maryland, College Park, and NASA/GSFC) did the study.

**Stubborn Drought Choking the Western U.S., Stressing Plants and Humans Alike**; Mar. 12; *Philadelphia Inquirer, Kansas City Star, Biloxi* (Mississippi) **Sun Herald, Centre City** (Pennsylvania) *Daily, The* (San Jose, CA) *Mercury News, The Arizona Republic*; **Bill Patzert** (NASA JPL) was interviewed by Faye Flam, staff reporter with the *Philadelphia Inquirer*, widely distributed to newspapers throughout the U.S.

**Scientists Find More Keys to the North Pacific Ocean's Climate**; Mar. 9; *Albuquerque Journal*; **Nicholas Bond, J.E. Overland** and **P. Stabeno** (NOAA Pacific Marine Environmental Lab), and **M. Spillane** (Univ. of Washington), discovered that sea surface tem-

peratures and sea level pressure in the North Pacific have undergone unusual changes over the last five years, leading scientists to believe factors other than those previously recognized contribute to the region's climate. Bill Patzert (NASA JPL) was also quoted.

**NASA Embarks on Sweeping Airborne Expedition;** Mar. 7; *Spaceflightnow.com*; An international team of scientists from NASA including **Ron Blom, Eric Rignot** and **Sassan Saatchi** of (NASA/JPL), and other research institutions embarked on a three-week expedition of discovery that will take them from the lush, dense rain forests of Central America to the frigid isolation of Antarctica.

**Fairmont NASA Facility to Back Up Weather Service Computer;** Mar. 1; *Clarksburg Exponent Telegram*; A backup system for the National Weather Service's forecasting supercomputer soon will be located at the NASA facility near Clarksburg, West Virginia.

**Drought Interviews;** Mar. and Apr.; **Bill Patzert** (NASA/JPL) had a live interview (for 7 am "rush hour") with Jack Popejoy, Lead News Anchor for *KFWB* (980 am radio in LA) on Mar. 2; interviewed with Jake Armstrong, reporter with *LaCanada Valley Sun*; interviewed on Mar. 22 with Steve Gonzalez from *Metro Networks News, KABC radio* (790 am in LA); was interviewed on CNN by Chuck Conder, aired on *CNN & CNN Headline News* Mar. 17 & 18; and Jason Kandel, reporter with the *LA Daily News*, for a front page article, "Record-setting temperatures top out at 96 in Southland" on Mar. 22; interviewed by Lori Fugii, producer for the *NBC Nightly News (NBC National News)*, for an "In Depth" story, "Dry, Dry West;" and in Mid-April 2004 Bill Patzert was

profiled by Debra Sass, writer with the Metropolitan Water District of Southern California's *Aqueduct Magazine*. Bill is profiled as "one of the 12 people that most influence California water policy."

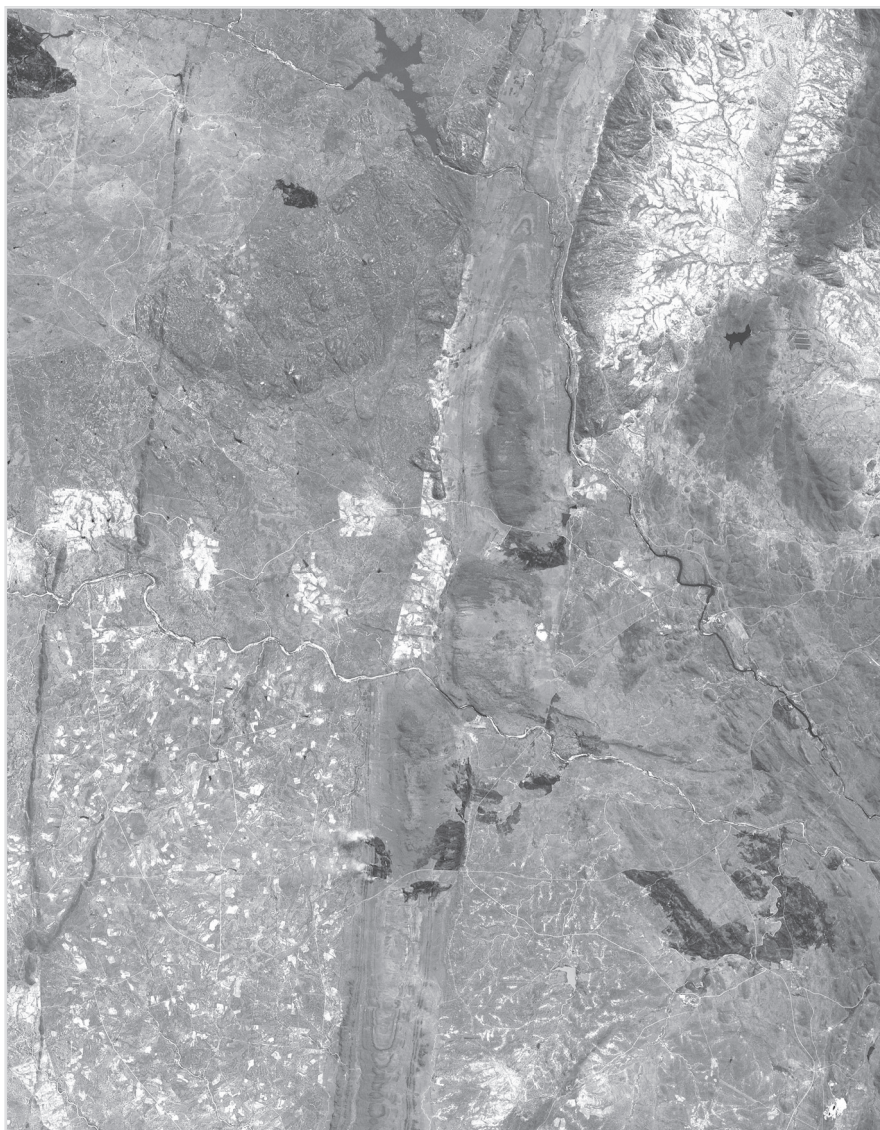
**Pollutants Hide in Sea-Bound**

**Clouds;** Feb. 29; *National Public Radio, Scienceblog.com, Innovation-Report.com, ScienceDaily.com*; **James Crawford** (NASA Langley) interviewed about the first evidence more regional pollution lurks in clouds than in clear skies off the Asian coastline.



The Great Dyke in the southern Zimbabwe Craton is one of the most remarkable rock formations in the world. A "craton" is a term geologists use to describe Earth's oldest continental regions. Zimbabwe's Great Dyke, runs vertically through the center of this scene. The dyke stretches about 530 km across the craton and varies from between 3 and 12 km wide long its length.

The scene was acquired on August 29, 2000, by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard NASA's Terra satellite. Several burn scars (dark patches) bruise the landscape in this scene, including the aftermath of a fire that is still burning atop the dyke in this scene. The twin plumes of gray smoke billowing westward mark the location of the fire, situated toward the bottom center of the image. Image courtesy NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team



### **EOS Science Calendar**

#### **August 17-19**

MODIS Vegetation Workshop II, University of Montana, Contact: Steve running, (406) 243-6311, [swr@ntsg.umt.edu](mailto:swr@ntsg.umt.edu)

#### **October 27-29**

SORCE Science Team Meeting, Meredith, New Hampshire URL: [lasp.colorado.edu/sorce/2004ScienceMeeting.html](http://lasp.colorado.edu/sorce/2004ScienceMeeting.html)

### **Global Change Calendar**

#### **May 23-28**

American Society for Photogrammetry and Remote Sensing (ASPRS) Annual Conference, Denver, CO. URL: [www.asprs.org/denver2004](http://www.asprs.org/denver2004)

#### **June 16-24**

8th Biennial HITRAN Conference, Cambridge, MA. URL: [cfa-www.hanuand.edu/HITRAN](http://cfa-www.hanuand.edu/HITRAN)

#### **July 12-23**

International Society for Photogrammetry and Remote Sensing (ISPRS), Istanbul, Turkey. URL: [www.isprs2004-istanbul.com](http://www.isprs2004-istanbul.com)

#### **July 18-25**

35th COSPAR Scientific Assembly, Paris, France. URL: [www.copernicus.org/COSPAR/COSPAR.html](http://www.copernicus.org/COSPAR/COSPAR.html)

#### **August 1-6**

Stratospheric Processes and their Role in Climate (SPARC) 3rd General Assembly, Victoria, British Columbia, Canada. URL: [sparc.seos.uvic.ca](http://sparc.seos.uvic.ca)

#### **August 1-6**

The Ecological Society of America 89th Annual Meeting, Portland, OR. URL: [www.esa.org/portland/](http://www.esa.org/portland/)

#### **August 16-26**

The European Space Agency's (ESA) 2nd ENVISAT Summer School on Earth System Monitoring & Modeling, Frascati, Italy. URL: [envisat.esa.int/envschool/](http://envisat.esa.int/envschool/)

#### **September 4-9**

The 8th Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC), Christchurch, New Zealand. URL: [www.igaconference2004.co.nz](http://www.igaconference2004.co.nz)

#### **September 13-17**

SPIE's Sensors, Systems, and Next Generation Satellites X (RSO3), Maspalomos, Gran Canaria, Spain. Contact

Steven Neeck, [steve.neeck@nasa.gov](mailto:steve.neeck@nasa.gov). URL: [spie.org/info/ers](http://spie.org/info/ers)

#### **September 20-24**

International Geoscience and Remote Sensing Symposium (IGARRS), Anchorage, Alaska. URL: [www.ewh.ieee.org/soc/grss/igarss.html](http://www.ewh.ieee.org/soc/grss/igarss.html)

#### **October 13-16**

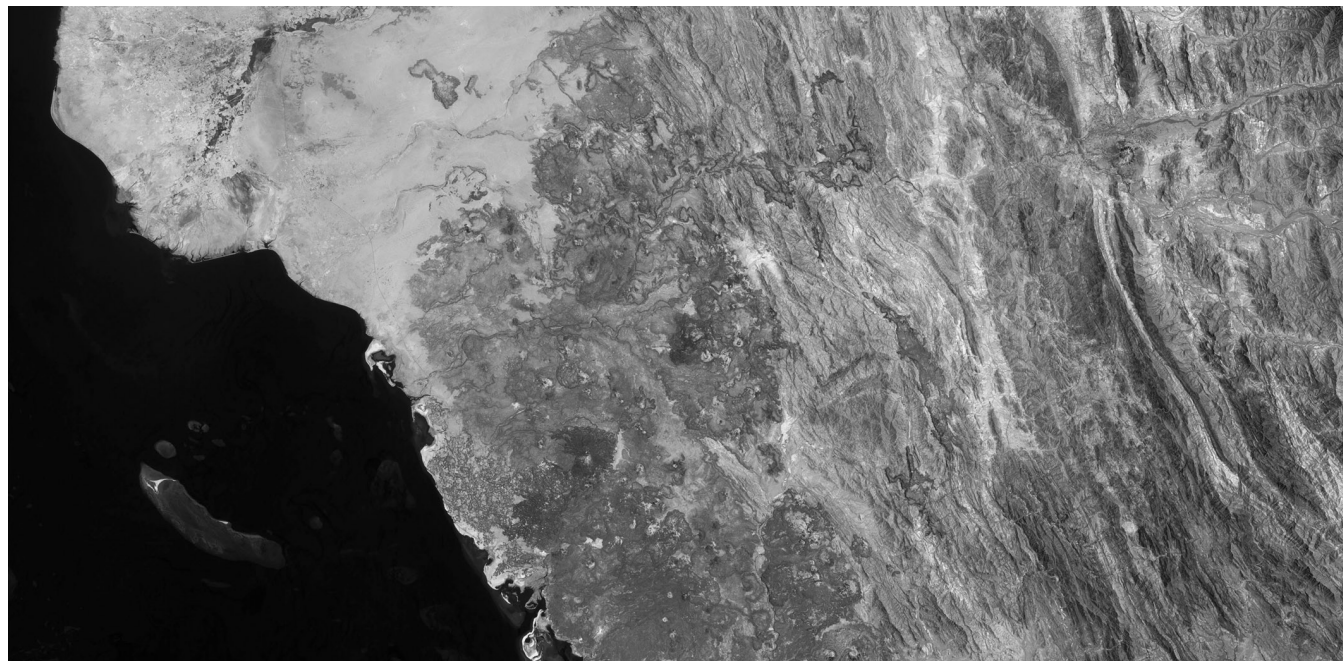
Surface Ocean Lower Atmosphere Study (SOLAS) 2004 Open Science Conference, Halifax, Nova Scotia, Canada. URL: [www.uea.ac.uk/eng/solas/ss04.html](http://www.uea.ac.uk/eng/solas/ss04.html)

#### **November 8-12**

SPIE's Fourth International Asia-Pacific Environmental Remote Sensing Symposium, Honolulu, Hawaii. Abstracts due April 26, 2004. URL: [spie.org/conferences/calls/04/ae/](http://spie.org/conferences/calls/04/ae/)

Dark-colored volcanic cones sprout from an ancient lava field known as Harrat Al Birk along Saudi Arabia's Red Sea coastline. Many such lava fields dot the Arabian Peninsula and range in age from 2 million to 30 million years old. This image was acquired by Landsat 7's Enhanced Thematic Mapper plus (ETM+) sensor.

Image provided by the USGS EROS Data Center Satellite Systems Branch as part of the Earth as Art II image series





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