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EDITOR'S CORNER

Michael King
EOS Senior Project Scientist

I'm happy to report that on June 19, NASA's Quick Scatterometer (QuikSCAT) satellite was launched aboard an Air Force Titan II launch vehicle from Vandenberg Air Force Base. QuikSCAT's SeaWinds microwave scatterometer will provide new near-surface wind speed and direction measurements under all weather and cloud conditions over the Earth's oceans. The satellite achieved its initial elliptical orbit with a maximum altitude of about 800 km above the Earth's surface about an hour after launch.

During the first two weeks after launch, QuikSCAT fired its thrusters as many as 25 times to circularize and gradually fine-tune its polar orbit. Eighteen days after launch, the SeaWinds instrument was turned on for the first time. Members of the project engineering and science teams spent the next 12 days performing detailed checks of the instrument and initially calibrating its radar backscatter and ocean wind measurements. Although calibration and validation of the measurements will continue for several months, QuickSCAT formally began its primary mission of mapping ocean wind speed and direction, starting about 30 days after launch. The primary mission is scheduled to continue for two years.

QuikSCAT is managed for NASA's Office of Earth Science by the Jet Propulsion Laboratory, which also built the SeaWinds scatterometer instrument and will provide ground science processing systems. NASA's Goddard Space Flight Center managed development of the satellite, designed and built by Ball Aerospace & Technologies Corp., Boulder, CO. Additional information on QuikSCAT can be found on the QuikSCAT web site at http://winds.jpl.nasa.gov/missions/quikscat/quikindex.html.

Launch of the EOS flagship satellite Terra (formerly known as AM-1) has been delayed until no earlier than September 13, 1999. A rash of Pratt & Whitney RL-10 engine failures on Delta launch vehicles (similar to the Atlas IIAS vehicle slated to launch Terra) prompted the decision to postpone the launch. Consequently, a flight constraint on the RL-10 engine has been issued by Pratt & Whitney. With the uncertainty of the resolution of the flight constraint, NASA has decided not to proceed with preparations for fueling the Terra spacecraft (the next major step in the launch flow). Terra will not be launched until there is the highest confidence that all aspects of the launch will meet with success.

The EOS Project Science Office and the Goddard Public Affairs Office organized a Science Writers Workshop at the American Geophysical Union headquarters in Washington, DC on June 24. The goal of the meeting was to educate science journalists from *Nature*, *Scientific American*, *Discovery On-Line*, *Physics Today*, and other publications on the EOS programs, global-change science objectives, and information resources. Several prominent scientists and NASA officials spoke on EOS missions, science, and media resources. On June 25, workshop participants attended a series of lectures and demonstrations by EOS project and data managers at Goddard Space Flight Center. An EOS Global Change Media Directory was also distributed at the workshop. The Media Directory provides journalists with a ready source of international expertise on global climate change and policy. The 237 scientists listed in the directory represent more than 30 scientific disciplines emphasized by the EOS program. The workshop and Media Directory together represent an invaluable resource for accurate and timely dissemination of EOS mission and science information to major media outlets.

Landsat 7 continues to perform very well three months after its successful launch from Vandenberg Air Force Base on April 15. Since then, in addition to the normal post-launch checkout activity, a great deal of effort has been devoted to extracting and publicizing a few scenes for media and public relations purposes. The Landsat 7 Team is now returning to the critical task of completing the on-orbit independent verification plan required to acclimate the instrument to its space environment. Landsat 7 imagery has now been geo-referenced to the Worldwide Reference System (WRS) Path-Row coordinate system. This milestone achievement allows consistent correlation with other Landsat imagery, and opens the door for operational data acquisition and ordering. Landsat 7's orbit is now 8 days out of phase with Landsat 5, providing maximum Earth coverage for monitoring acute geophysical phenomena like floods, forest fires, and other natural disasters. The first Landsat 7 imagery was made available to the public in late July. Full scenes that have been corrected for sensor effects and spacecraft geometry (Level One processing) will become available from the EROS Data Center in Sioux Falls, South Dakota at a price of $600 each. More information on Landsat 7 and the Landsat program can be found on the Landsat program web site at: http://geo.arc.nasa.gov/sge/landsat/landsat.html.

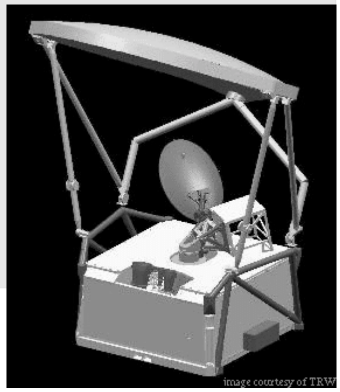
The EOS Data and Information System (EOSDIS) recently conducted data flow and ingest/archive/distribution readiness tests, complemented by Terra End-to-end Science System (TESS) tests. A Mission Operations and Science System (MOSS) also took place in late July. These tests have revealed satisfactory network performance for the current requirements, but the network may not be able to support system distribution throughput for significant requirement increases. Much of the processing for EOS data will be done via Science Investigator-led Processing Systems (SIPS), and will contain high-speed ingest capabilities for data products in the next major release of EOSDIS software, which will be installed at the DAACs beginning in late July, and extending through November. All processing, ingest, and distribution software is expected to be in place in time for operational data flow from Terra.

Joint Advanced Microwave Scanning Radiometer (AMSR) Science Team Meeting

— E. Lobl (elena.lobl@msfc.nasa.gov), AMSR-E Science Team Coordinator, Earth System Science Laboratory, University of Alabama in Huntsville

ADEOS-II AMSR homepage:
se.eorc.nasda.go.jp/eorc/AMSR/amsr EOS

PM-1 AMSR-E homepage:
wwwghcc.msfc.nasa.gov/AMSR



A Joint AMSR Science Team meeting was held in Firenze, Italy, 19 March 1999, immediately following the Microrad '99 Specialists meeting. Most of the discussion revolved around validation of the AMSR products. A summary of the Japanese Validation plan was presented.

Dr. A. Shibata (ADEOS-II AMSR Lead Scientist) presented a summary of the Japanese Validation plan, including the status of the AMR aircraft-radiometer refurbishment. The pre-launch activities (1999-2000) rely mostly on generating 'match-up' data sets with SSM/I and TMI. The data used to generate these data sets would be from radiosondes, buoys, radars, and GTS-provided snow-depth measurements. Soil-moisture data will come from GAME IOP in Tibet and Thailand and SGP'99. The field experiments and campaigns considered are:

- continuous monitoring of two ground-based radiometers on islands off the coast of Japan (Hekurajima and Aogashima),
- AMR flights in May-July 2000 over Nagaoka,
- one ground-based radar in the Bay of Wakasa, and possibly one in Siberia,
- an automatic snow-station network in Siberia.

The post-launch validation would consist of a continuation of the pre-launch activities. These activities will be augmented by:

- AMR flights in May-July 2001 in Tibet, for precipitation validation
- AMR, AMSS, PSR, AVIRIS, air-borne laser altimeter, and SAR flights in the Okhotsk Sea, Arctic and Antarctic Oceans, and Alaska, for sea-ice validation,
- campaigns in Tibet and Siberia to measure snow depth, density, and grain size in Jan-Feb 2001 and 2002, for snow validation,
- AMR flights in Tibet, May-July 2001, Thailand, April-June 2002, and Mongolia, Aug-Oct 2002, for soil-moisture validation.

The AMR is undergoing a major refurbishment. The main change is an improved in-flight calibration scheme. There will be 3 test flights to validate the correct performance of the AMR. E. Sakai (NASDA/EOSD) presented to the Joint Science team the results from the February data format meeting; both instruments will have the same data format, and this format will be the same as the EOSDIS-recommended data format.

C. Kummerow (AMSR-E Precipitation group lead) presented a detailed summary of the updated AMSR-E Precipitation Validation Plan. The main components of this plan are: 1) Extending the TRMM ground-radar network to higher latitudes, 2) operating the mobile (10 cm) radar (to obtain beam-filling statistics, 3) freezing-level retrieval, vertical-profile statistics, cumulus/stratus confirmation), and 4) an intensive field campaign (using the ER 2 and a microphysics aircraft), in 2002 in Alaska/Seattle. A similar mission is planned for 2004 in Punta Arenas, Chile.

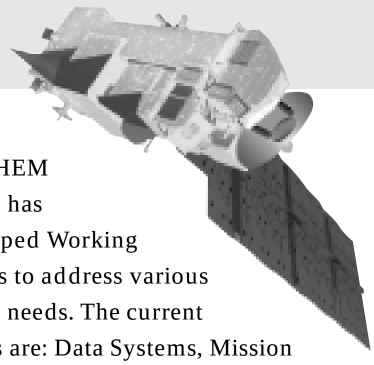
F. Wentz (AMSR-E Ocean suite lead) showed some results from his TMI work, where he found wind-speed (roughness) anomalies upwind of Hawaii and off the southern tip of Africa. He discussed a possible validation plan for the wind and SST retrievals in these areas.

P. Gudmansen (Professor emeritus, Technical University of Denmark) presented his proposal for GRASP, a validation campaign for sea ice in the Arctic Ocean, near the north coast of

(Continued on page 19)

Report on the EOS CHEM Science Team Meeting

— Anne Douglass (douglass@persephone.gsfc.nasa.gov), NASA Goddard Space Flight Center, Greenbelt, MD



An EOS CHEM science team meeting was held April 12-14, 1999 (Monday – Wednesday) at the Convention Center in Pasadena CA. The CHEM Project now has two meetings annually. The spring meeting is oriented towards data products and science issues which are anticipated to be addressed using CHEM data, while the fall meeting [the Chemistry Annual Project Steering Meeting (CHAPS)] is oriented towards project issues. The April 1999 meeting had two purposes. The first was to enhance the CHEM science team by developing interactions between the data providers (instrument teams and their PIs) and data users (IDS investigators, members of the instrument science teams not directly involved in data production, and the outside science community). The second was to discuss validation needs for CHEM. The agenda included presentations on the four CHEM instruments: the Microwave Limb Sounder (MLS), High Resolution Dynamics Limb Sounder (HIRDLS), Tropospheric Emission Spectrometer (TES), and Ozone Monitoring Instrument (OMI), and presentations on sources of data in the CHEM timeframe such as the Solar Stellar Irradiance Comparison Experiment (SOLSTICE), and the ENVISAT mission, which ESA will launch in 2000. There was also a presentation on the planned standard data assimilation products expected in support of the mission. In addition, there were more than 30 contributed science talks and posters.

The CHEM Project has developed Working Groups to address various project needs. The current groups are: Data Systems, Mission Operations, Education/Outreach, Algorithm, and Validation. The Working Groups met at various times during the first two days of the meeting, and reported to the full group on Wednesday. Working Group reports from this meeting and general information about these sub-groups can be found on the CHEM web site (http://eos-chem.gsfc.nasa.gov). Part of the final morning was spent discussing validation needs for EOS CHEM, and the goal of planning validation campaigns that will meet the dual goals of satisfying CHEM needs while addressing focussed science questions. A presentation on the SAGE III Ozone Loss and Validation Experiment (SOLVE) provided a concrete example of this strategy. Discussion at this meeting was focussed on the validation needs of the CHEM platform, emphasizing that several constituents are measured by more than one instrument. Science questions to be addressed in the manner of SOLVE, while fulfilling these validation needs, will be the subject of the Workshop for Integration of Satellite Calibration/Validation and Research-Oriented Field Missions in the Next Decade to be held in August 1999 in Snowmass, CO.

Major Accomplishment:

The PICASSO-CENA proposal (Dr. David Winker, principal investigator) was selected for development under the NASA Office of Earth Science's Earth System Science Pathfinder (ESSP) program. PICASSO-CENA is the next phase in NASA's strategy to understand the impact of aerosols and clouds on the Earth's climate system. The primary goal of the mission is to provide global, high-spatial-resolution measurements of the vertical distribution and optical properties of tropospheric aerosols and clouds that will significantly improve our understanding of the effects of aerosols and clouds on the Earth's radiation budget. It combines a 3-channel lidar with innovative passive sensors to obtain this unique data set. A key aspect of PICASSO-CENA is flying in formation with NASA's EOS-PM and CloudSat satellites to produce a coincident global data set that is essential for accurate quantification of aerosol and cloud radiative effects. PICASSO-CENA is a joint enterprise between the NASA Langley Research Center (LaRC), the French Centre National d'Etudes Spatiales (CNES) and Institut Pierre Simon Laplace (IPSL), Ball Aerospace and Technologies Corporation (BATC), Hampton University (HU), and other university partners. The PICASSO-CENA spacecraft will be launched in 2003 and will operate for 3 years.

CERES Science Team Meeting

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

The 19th Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held in Williamsburg, VA on April 27-29, 1999. The major items of business for this meeting were: (1) identifying current problems in cloud validation and expected ways of reducing those to a level acceptable for validation and archiving; (2) identifying current problems in CERES Surface and Atmospheric Radiation Budget (SARB) validation and expected ways of reducing those problems to a level acceptable for validation and archiving; (3) clarifying the approaches to improving angular distribution models (ADMs) and identifying when we begin producing the second edition of the CERES-Tropical Rainfall Measuring Mission (TRMM) products; and (4) ensuring that the instrument calibration is stable, that we optimize the time of data collection for CERES-TRMM, are fully prepared to rapidly validate the AM (Terra) data, and that we have a firm and rigorous basis for stating the uncertainties in the CERES measurements

Bruce Wielicki (NASA Langley Research Center, LaRC), CERES Co-Principal Investigator, opened the meeting with an EOS program status report. The Earth Observing System morning satellite (Terra) is now scheduled to be launched no sooner than September 13, 1999. EOS-PM is still on schedule for a December 2000 launch.

Instrument Status: TRMM, Terra, and EOS-PM

Leonard Kopia (LaRC) presented details of the investigation into the voltage converter anomaly on the CERES instrument flying on the TRMM spacecraft. The team recommended replacement of all low-voltage converters in the five CERES flight models. Kopia also reported that all instrument build and test activities are on schedule. Kory Priestley (LaRC) showed that calibration goals continue to be met and exceeded. Ground-to-orbit calibrations are consistent to within 0.12, 0.08, and 0.29% for the total, window, and shortwave (SW) channels, respectively. On-orbit results show no significant gain change in any channel. Bruce Wielicki reviewed the CERES/TRMM operations strategy for supporting field experiments. The first priority is to conserve the instrument until the Terra launch to conduct intercalibrations between the two CERES instruments. Robert B. Lee III (LaRC) discussed Terra launch readiness and on-orbit operations for calibrations and consistency checks.

ERBE-like Data and Validation

Dave Young and Richard Green (both of LaRC) gave an update on ERBE-like validation. A comparison of tropical means from CERES during 1998 and Earth Radiation Budget Satellite (ERBS) scanner 5-year averages from 1985-89 showed significant differences. The agreement in clear-sky values and the disagreement in all-sky values indicates that changes in cloud properties between the Earth Radiation Budget Experiment (ERBE) and CERES time periods are responsible for the differences.

Yong Hu (Hampton University, HU) examined the discrepancy between theoretical and observed cloud absorption. Using the Precipitation Radar on TRMM to identify deep convective clouds, he determined from the corresponding CERES measurements that the mean albedo of such clouds is about 0.70 for precipitating deep convection and 0.74 for non-precipitating deep convection. All clouds gave 11-μm brightness temperatures <205 K. Theoretical albedos ranged from 0.74 to 0.79.

Patrick Minnis (LaRC) gave an overview of the CERES cloud optical property retrieval subsystem and showed good initial results for cloud physical and microphysical property retrievals. The Visible-Infrared Scanner (VIRS) calibration appears to be stable. Surface-based retrievals of cloud properties at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) and the Tropical Western Pacific (TWP) sites compared well with CERES-derived cloud properties.

Norman Loeb (HU) summarized recent findings of the ADM team. Albedo estimates based on ADMs using fixed optical-depth classes show a large dependence on viewing geometry. Albedos based on ADMs which use percentiles of cloud optical depth show substantially less dependence on viewing geometry and agree with direct integration albedos. Results from the Polarization and Directionality of the Earth's

Reflectances (POLDER) experiment demonstrated the importance of defining ADMs by cloud fraction, cloud optical depth, and cloud phase.

Tom Charlock (LaRC) presented a status report on the validation of SARB data products. He noted several improvements to the radiative transfer code, and reviewed several ongoing validation experiments.

Education and Outreach

Lin Chambers (LaRC) gave a brief update on recent activities of the Students' Cloud Observations On-Line (S'COOL) project, which is a part of the Outreach and Education programs at NASA/LaRC. Under this project, students in secondary schools around the world make observations of the atmosphere and submit them to the S'COOL database. These observations are then used for validation of coincident satellite data. At present, over 250 schools from the U.S. and 20 other countries on all continents are participating in the S'COOL project.

Invited Presentations

Two EOS Earth Science System Pathfinder (ESSP) missions have been selected to fly in formation with EOS-PM to provide cloud profiling data. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations - Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) includes a lidar instrument, and the CloudSat mission will fly a cloud radar. Dave Winker (LaRC) gave an overview of the PICASSO-CENA mission. The payload consists of a lidar, an oxygen A-band spectrometer, an imaging infrared radiometer, and a wide-field-of-view camera. Data from these instruments will be used to measure the vertical distributions of aerosols and clouds in the atmosphere, as well as optical and physical properties of aerosols and clouds which influence the Earth's radiation budget. Taneil Uttal (NOAA) gave a brief summary of CloudSat capabilities for obtaining vertical profiles of clouds. She then described the SHEBA (Surface Heat Budget of the Arctic) experiment and showed some results on observations of Arctic clouds using lidar and radar instruments.

Working Group Reports

Instrument Working Group: Robert B. Lee III led the Instrument Working Group (WG) meeting in discussions of the accuracy of the CERES instrument on TRMM. Measurement accuracy and precision goals have been satisfied. The group is examining the instrument ground calibration data in an attempt to understand the 1% inconsistency in the ERBE-like 3-channel checks performed by Kory Priestley for deep convective clouds (0.8%), and Richard Green on the Tropical Mean day/night check (1.2%). This inconsistency is within the CERES goal of 1% SW absolute calibration accuracy; calibration changes are not currently planned.

Cloud Working Group: Patrick Minnis led a discussion of cloud retrieval, archival, data dissemination, and validation issues.

Q. Han (U. Alabama-Huntsville) discussed the uncertainties in cloud retrievals induced by the variation of ice crystal shapes in clouds. He quantified large uncertainties caused by inaccurate ice crystal shapes, which are reflected in large errors in bidirectional reflectance functions and optical depth.

Ron Welch (U. Alabama-Huntsville) gave examples of a new cloud classifier that utilizes VIRS data. He also presented results for a 3-D cloud study in which he simulated radiance patterns in order to study the errors inherent in using plane-parallel radiative-transfer theory in satellite retrievals.

Qing Trepte (SAIC) presented improvements to the CERES cloud-masking techniques for both day and night time. Pat Heck, Analytical Services and Materials, Inc. (AS&M), discussed improved techniques implemented in the cloud optical property retrieval algorithm for determining cloud phase using 1.6-µm data. Sunny Sun-Mack (SAIC) presented new databases of 1.6-µm clear-sky products, including maps of 1.6-to-0.63-µm reflectance ratios that are used in the cloud mask. Michael King (GSFC) commented that he could provide new directional and bidirectional models for snow and ice that would assist with cloud masking.

Jay Mace (U. Utah) summarized cloud property retrievals from the ARM program. The availability of data from the SGP, TWP, and North Slope of Alaska sites was included in discussion of CERES validation. Michael King suggested that he reduce the data volume for the CERES team by matching the surface-based retrievals with TRMM and Terra overpasses.

Chuck Long (Penn State) presented a summary of his cloud-cover retrievals from a NOAA hemispheric sky imager, including a comparison of these retrievals with cloud amounts derived from satellite data using the Layered Bispectral Threshold Method of Minnis.

Surface and Atmospheric Radiation Budget (SARB) Working Group: The SARB and Surface-only Working Groups met jointly. The meeting was co-chaired by Thomas Charlock and David Kratz (both from LaRC).

Bill Collins (NCAR) gave an invited presentation on the results from an experiment in which aerosol radiative properties were forecast over areas of the Indian Ocean. In the first part of this experiment, a chemical transport model (CTM) was used with aerosol sources and meteorological data to produce the forecast. In the second part, satellite data were assimilated with the CTM. Comparisons of the forecasts with and without satellite data assimilation showed significant differences.

Fred Rose (AS&M) gave a report on a wide range of SARB activities. Rose showed comparisons of several SW and longwave (LW) parameters derived in the SARB subsystem with corresponding single-satellite-footprint (SSF) parameters from satellite retrievals. Comparison of calculated and observed top-of-atmosphere (TOA) albedos over cloudy scenes showed significant differences as a function of cloud optical depth and phase. These were attributed to the lack of sensitivity to cloud optical depth and phase in the ADMs used in CERES processing. Rose also showed that the inclusion of the CERES window channel in the constrainment algorithm helped to better constrain the lower tropospheric humidity (LTH) and the surface skin temperature. Several improvements were implemented in the Fu-Liou model and SARB processing as a result of these studies.

John Augustine (NOAA) and Chuck Long apprised the WG of surface-measured data available from six locations of the NOAA SURFRAD network for validation of CERES / SARB products. Augustine described the instrumentation and the radiation and ancillary measurements made at these facilities. Long described an innovative method for estimating effective cloud amounts at a site directly from the solar radiation measurements.

Tim Alberta (AS&M) presented results of an analysis of surface-measured fluxes from the CERES / ARM / GEWEX Experiment 2 (CAGEX2) and the CERES ARM Validation Experiment (CAVE). In many of these measurements, the diffuse radiation was substantially less than that computed with the Fu-Liou code even without aerosols. Many of the pyranometers registered negative values for diffuse radiation during the night. The magnitude of these negative values was found to be related to the net LW flux at the instrument. A correction algorithm for diffuse radiation was developed based on this relationship, and daytime diffuse-radiation measurements were corrected using this algorithm.

Martial Haefflin (Virginia Polytechnic Institute & State University, VPI&SU) presented results of a simulation of physical processes inside a pyranometer, which can be used to quantify uncertainties in SW radiation measurements. Haefflin showed that monitoring the temperature of the inner dome is important for modeling the energy exchanges between the detector and the surroundings.

Seiji Kato (HU) compared CERES retrieved and modeled TOA irradiances for scenes containing warm stratus clouds. Cloud parameters used in the model computations were based on measurements made at the ARM SGP site in January 1998. He concluded that CERES retrievals overestimated TOA albedo over thick clouds, and underestimated it over thin clouds, and he stressed the need for stratifying ADMs by cloud optical depth.

John Augustine apprised the group of the Global Air-ocean IN-situ System (GAINS), a NOAA program from which valuable data can be obtained for validation of CERES retrievals. The GAINS program launches 60-ft-diameter balloons, which carry a 200-lb payload and stay at 60-70-thousand feet for extended periods of time. These balloons will make radiometric measurements and launch dropsondes.

Thomas Charlock (LaRC) apprised the group of the Ultra Long Duration Balloon (ULDB) program being planned by NASA / GSFC and the Wallops Island facility. These balloons will stay at about 35 km for extended periods of time, and will carry Eppley pyranometers and other scientific payloads. The first balloon will be launched in the Southern Hemisphere in December 2000, and will stay up for about 30 days. Subsequent balloons will stay up for up to 100 days.

Shashi Gupta (AS&M) discussed the problem faced by the Meteorology, Ozone, and Aerosol (MOA) subsystem during May-June 1998 because of the interruption of the ozone data stream from the Stratospheric Monitoring-group Ozone Blended Analysis (SMOBA / NCEP) which is the primary source of ozone for MOA. He presented a plan to deal with such interruptions in the future.

CERES ADM Working Group: Norman Loeb led the ADM WG meeting with a general overview of critical ADM / inversion research issues.

Yong Hu showed some early comparisons between clear-sky SW Bidirectional Reflectance Distribution Functions (BRDFs) from CERES Rotating Azimuth Plane Scanner (RAPS) data with those from theory. Overall, the CERES BRDFs tend to show more limb brightening relative to theory. One possible cause for this may be cloud contamination of oblique CERES-RAPS views not observed by the VIRS on TRMM, which observes the scenes only at near-nadir viewing zenith angles. Hu's results emphasize the need for a means of improving cloud screening for shallow CERES viewing zenith angles.

Lin Chambers (LaRC) presented results of a theoretical examination of Norman Loeb's "percentile-approach" for constructing ADMs. She found that retrieved fluxes show smaller angular bias and rms errors using the percentile-approach than the "fixed-tau" approach (which ignores retrieval errors in determining ADM scene types). She points out, however, that even the percentile approach does not entirely correct for the influence of 3D cloud effects (e.g., shadowing in the forward scattering direction).

Shalini Mayor (AS&M) presented spectral clear-sky BRDFs over the ARM SGP site inferred from the Unmanned Aerospace Vehicle (UAV) Multispectral Pushbroom Imaging Radiometer (MPIR) instrument and the CERES helicopter. These were compared with BRDFs derived from Geostationary Operational Environmental Satellite (GOES) data (at the TOA). RMS differences (comparing angular bins) were generally between 15-30% for a solar zenith angle of 45°, and increased to 30-45% for a solar zenith of 75°. Surface wetness was found to be an important factor.

Norman Loeb examined the anisotropy in CERES LW- and window-channel radiances as a function of cloud properties in overcast conditions over ocean. While limb darkening was shown to increase dramatically with decreasing IR emissivity (especially in the window channel), there was less sensitivity to cloud-top temperature.

Bill Collins presented comparisons of clear-sky TOA outgoing LW radiation (OLR) from three satellite Earth-radiation missions with theoretical calculations. Differences were shown to depend systematically on column-mean relative humidity (RH).

Richard Green (LaRC) led a discussion on the definition of flux for CERES. It was proposed that CERES radiance-to-flux conversion be first performed relative to a pixel's location at the Earth's surface, and then adjusted to the TOA (defined at 30 km) by applying a ~1% correction to account for the flux dependence on height. The question of whether a 30-km height is appropriate generated much discussion.

Time Interpolation and Spatial Averaging (TISA) Working Group: David Young led discussions of software development, current temporal and spatial averaging studies, ongoing CERES ERBE-like validation efforts, and the first results from the CERES enhanced temporal interpolation algorithms using data from geostationary satellites. Maria Mitchum (LaRC) presented an overview of the status of the operational code for the seven TISA subsystems; all subsystems have been delivered to the Langley Distributed Active Archive Center (DAAC). Recent algorithm changes include the inclusion of overlap data and a data filter for striping in the geostationary data. Near-term plans include geostationary satellite data inter-calibrations using VIRS data, and modifications to handle CERES data from multiple instruments. Takmeng Wong (LaRC) presented a technique for identifying and removing bad data records from the GOES-8 data files. This data filter, which compares the mean and standard deviation of radiances from consecutive scan lines, has been incorporated into the operational code. Stéphanie Weckmann (VPI&SU) presented a technique for removing the spatial resolution bias between monthly mean flux estimates from scanner and non-scanner measurements. The results show that simulation of the non-scanner field-of-view with the higher resolution gridded scanner data eliminates seasonal variations in scanner / non-scanner correlations. The working group discussed the first results from Subsystem 10. Comparisons of monthly mean fluxes derived with and without the use of geostationary data were shown.

Investigator Presentation Highlights

Bryan Baum (LaRC) presented a technique for identifying pixels in which a thin ice cloud overlaps a thick water cloud using data from the MODIS Airborne Simulator (MAS). The technique is based on properties of water and ice clouds computed with a discrete-ordinate code and uses measured reflectance at 1.63 µm and brightness temperature at 11 µm.

Don Cahoon (LaRC) presented results from the CERES ARM Radiation Experiment (CARE) conducted during August 1998 at the ARM SGP site. Cahoon also described the CERES validation facility being set up on the Chesapeake Lighthouse platform, about 25 km east of Virginia Beach, VA, in the Atlantic ocean. This facility is expected to be operational by August of 1999 and will be used to monitor spectral SW radiation reflected from the ocean surface.

Robert Cess (State University of New York at Stony Brook) presented results of a study conducted by Meredith Croke, a high school student who worked with him last summer. This study showed the relationships between the change in global mean climate (represented by global mean T_s) and cloudiness over three different regions of the U.S., namely, the coastal southwest, the coastal northeast, and the southern plains. Cloudiness in all three regions was found to increase with increasing T_s. Cloudiness was also correlated with other indices of regional climate.

Thomas Charlock (LaRC) presented an essay on detecting a climate-change signal and the importance of a continuous long-term record of broadband TOA ERB for its detection. He showed from the results of a simple 1-D radiative-convective model that, taking into account the heat taken up by the deep oceans, a substantial imbalance in global-annual TOA ERB is required to cause a warming trend. He showed further that the CERES instrument exhibits sufficient year-to-year stability and precision to measure the TOA imbalance needed to produce a warming trend. Charlock stressed the need to produce a long-term record of broadband TOA radiation budget and identified it as a key resource for refining and validating the next generation of coupled atmosphere-ocean climate models.

Jim Coakley (Oregon State University) gave a progress report on his new pixel-level cloud-retrieval studies. He is identifying techniques for extracting cloud information from clusters of fairly homogeneous cloud pixels in order to assist in deriving cloud properties for individual pixels.

Leo Donner (NOAA / GFDL) presented results of a General Circulation Model experiment in which a mesoscale component using vertical convective velocities, in addition to the mass fluxes, was added to the cumulus parameterization of the model. He suggested that the current parameterizations do not predict the ice formation and also miss the large radiative forcing associated with cumulus convection. Donner showed that the new parameterization is based on more explicit treatment of mesoscale processes. It needs less frequent and less penetrative convection to produce cumulus clouds. The resulting clouds exhibit more realistic microphysics and cloud-radiation interactions.

Alexander Ignatov (representing Larry Stowe, NOAA / NESDIS) presented results from continuing work on retrieval of aerosol properties from VIRS pixel-level data and current SSF product. Their algorithms retrieve aerosol properties from VIRS radiances in channels 1 and 2 (0.63 μm and 1.6 μm, respectively). He showed size distribution, Angstrom exponent, and the dependence of aerosol optical depth (AOD) on solar and viewing zenith angles.

Robert Kandel (LMD France) presented a brief overview of the TOA ERB measurements obtained during the last 25 years and examined the data looking for climate trends. He examined zonal mean OLR for the 40°N-to-40°S band averaged for mid-seasonal months over several years obtained from ERBE, ScaRaB, and CERES. He also examined the tropical means (averaged over 20°N-to-20°S) for SW and LW radiation looking for trends. He pointed to much variability within the system on regional scales but a weak trend, if any, on the global scale.

Bing Lin (HU) presented estimates of turbulent heat fluxes over tropical oceans derived from TRMM data. He summarized earlier work on the retrieval of turbulent heat fluxes and showed that retrievals from TRMM Microwave Imager (TMI) data have a much higher accuracy.

V. Ramanathan (Scripps Institution of Oceanography) presented an outline of a study of water vapor greenhouse effect (G) to be based on CERES data. Based on earlier work, he showed that the clear-sky value of G for the mid-latitude summer atmosphere was about 130 Wm^{-2}, which is much larger than for any other constituent of the atmosphere. Ramanathan showed further that the weighting function for G is distributed uniformly throughout the troposphere, and that water vapor feedback on G was always positive contrary to Lindzen's hypothesis.

David Randall (Colorado State University) presented early results from a futuristic climate model which is also easily compatible with CERES data. It is a finite-difference model in which all except 12 grid boxes are hexagons (the remaining 12 are pentagons). The spatial resolution of this model is roughly equivalent to the T42 resolution of the Community Climate Model (CCM3). A very attractive feature of this model is its quasi-isotropic geometry, i.e., grid boxes share walls with all neighboring boxes. This feature results in better performance by the model in the polar regions.

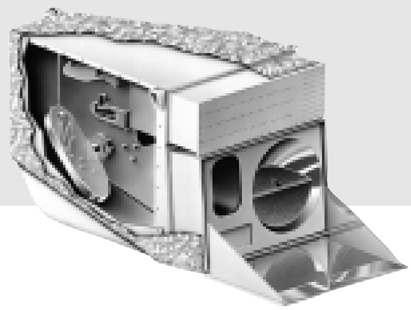
Shi-Keng Yang (representing Jim Miller, NOAA / National Centers for Environmental Prediction, NCEP) presented results of an examination of the radiation module used in the current version of the NCEP data assimilation model. The model yielded about 10-20 Wm^{-2} higher OLR over the tropical Pacific ocean when compared with ERBE results. He attributed this discrepancy to the very low values of upper tropospheric humidity found in the model.

Science Team Logistics

The next CERES Science Team meeting is scheduled for early December 1999 at the NASA Langley Research Center. The focus will be threefold: the progress of validation for clouds, ADMs, SARB, and TISA, new science results from the science team, and an examination of the first results from CERES on Terra.

Moderate Resolution Imaging Spectroradiometer (MODIS) Science Team Meeting Summary

— *Mike Heney and Deborah Howard*
(dhoward@pop900.gsfc.nasa.gov)
Science Systems and Applications, Inc.



The complete set of these minutes and attachments is available in Portable Document Format (PDF) on the MODIS Meetings Page at http://modarch.gsfc.nasa.gov/MODIS/SCITEAM/minutes.html.

Introduction

The MODIS Science Team meeting was held May 3–6 at the Greenbelt Marriott near Goddard Space Flight Center (GSFC). Vince Salomonson welcomed participants and said the meeting would focus on data products and algorithms. He suggested that a Terra meeting at the launch might be held in California to coincide with the launch of the Terra spacecraft, with the MODIS Protoflight Model (PFM) instrument on board.

Terra Project Status

Kevin Grady stated that three major reviews of the Terra spacecraft, the pre-ship, launch-vehicle readiness, and flight operations reviews, took place in April. Planned pre-launch activities include final spacecraft testing, propellant loading, and spacecraft closeouts. Remaining liens include demonstration of the operational readiness of all ground systems and a possibility that the recent Centaur anomaly during a Titan IV launch could impact Terra's launch. Grady reported that the spacecraft and instruments are ready for launch.

MODIS Sensor Status

Bruce Guenther presented a comparison of Level 1B (L1B) products with MODIS PFM instrument specifications. The electrical crosstalk on the instrument has been mitigated, with residual effects to be evaluated on orbit. Guenther presented a summary chart on the status of L1B parameters on a band-by-band basis; it will be maintained on the MODIS Characterization Support Team's (MCST's) Website. He reviewed the instrument activation sequence, identifying guiding objectives and providing major milestones.

MODIS Level 1A and Geolocation Status

Jeff Blanchette provided a status report on MODIS Level 1A (L1A) and geolocation code. Product Generation Executive (PGE) 01 was delivered in March, land control-point matching software has been developed, and island control-point software delivery is planned for July 1999. Blanchette reviewed the Geolocation Version 2.1 (at-launch) schedule. Version 2.2 will be worked on post-launch, and will include MODIS metadata and a robust G-ring algorithm.

MODIS L1B Readiness and Software Plans

Bruce Guenther provided an overview of MODIS L1B software readiness and plans for updates. He said that the current version, 2.1.5, incorporates all science updates received through March 1999. The next delivery, due at the end of May, includes many enhancements such as saturation fixes, a revised thermal-band look-up table, a refined uncertainty algorithm, and minor code fixes. Guenther presented the post-launch, L1B timeline that includes rapid-response changes, low-to-moderate-impact changes, and frequent look-up table updates resulting from calibration and characterization activities. Computer Resources of MCST (CROM) will likely develop and implement these updates.

Goddard DAAC Status for Production

Steve Kempler reviewed the status of the Goddard DAAC (GDAAC) ingest and production processing of MODIS data. He outlined the projected at-launch data flow and discussed the current system status. The GDAAC is conducting a series of Operational Readiness Exercises (OREs) to evaluate the system's functionality and performance. Kempler reported on the status of the Science Software Integration and Test (SSIT) system. Some manual intervention still is required for processes that should run automatically. The mitigation approach includes working on fixes to the automated system, documenting the interim manual process, and training operators.

MODAPS Status for Production and Distribution

Ed Masuoka reported on the status of the MODIS Adaptive Processing System (MODAPS) for production and distribution of MODIS Level 2, 2G, and 3 science data products. He said that the ingest portion of the Science Investigator Processing System (SIPS) interface works and that MODAPS is able to receive and ingest L1 products from the GDAAC. Masuoka reviewed open items, including Earth Science Data Type (ESDT) file mismatches, network bandwidth issues, and complete SIPS delivery. He discussed the status of at-launch PGEs, reported on n-day test results and provided a schedule for integration into the at-launch MODAPS system. He also outlined the Quality Assurance (QA) and Validation resources. A suite of software packages and some workstations are available for validation work onsite at GSFC.

GDAAC Archiving and Distribution of MODIS Data

Steve Kempler provided an update on the MODIS Oceans and Atmospheres data archiving and distribution by the GDAAC. The EROS Data Center (EDC) will process land data. He reviewed at-launch data flows and current operational status of launch-critical capabilities. The group discussed how to respond to the expected demand for early MODIS data products. Suggestions included producing data samplers to allow the user community to familiarize themselves with MODIS data and how to use it, and posting information on data product availability at conferences and in publications.

New Millennium Red Eye Proposal

Dennis Chesters notified the MODIS Science Team of a proposed project to obtain Landsat 7-like datasets from geosynchronous altitude, Red Eye. This will be proposed as a New Millennium project.

EDC Status for Archiving and Distribution

Brad Reed discussed the EDC status for MODIS Land data archiving and distribution. Full-up system tests will begin after the SIPS interface becomes available with EOS Core System (ECS) Version 5A. Data initially will be distributed to the public via File Transfer Protocol (ftp) and 8-mm tape. The ECS Version 5B release also will support distribution via CD. Issues to be resolved include data release approval, release scheduling, and questions of data visibility.

NSIDC Status for Archiving and Distribution

Greg Scharfen reviewed the National Snow and Ice Data Center (NSIDC) status for archiving and distributing Level 2 and 3 snow and ice data products. ECS Version 4PY is running in all three modes; version 5A is expected in June. NSIDC successfully participated in the Terra End-to-End Science System (TESS) test. Acceptance testing is ongoing, and participation in upcoming E-T-E and ground-system tests is planned. NSIDC will provide polar-gridded products at launch, with production volume dependent on MODAPS resources. Issues in work include the preparation of a draft operations agreement and an upcoming review of the SIPS-ECS Interface Control Document (ICD).

MODIS Routine Operations

Bruce Guenther presented the MODIS routine operations plan. A Field Campaign Form is available on the MCST Web site; code and look-up tables will be available via e-mail subscription. Calibration/Validation Workshops are planned and a set of Calibration-Applicable Archive Test Scenes (CAATS) will be used to test the impacts of calibration changes on Level 2 products. MCST envisions good communications with the user community. Level 1B data and code will be widely available, and the MCST Web pages will provide information describing the L1B products, calibration, and change histories.

Validation and Geolocation

Robert Wolfe described the MODIS Geolocation Validation and Operational QA plans. The geolocation process involves instrument characterization, ground control-point matching, error analysis, and production software model updates. The long-term focus will be on monitoring the stability of instrument geometric parameters and refining the geometric characterization of the instrument. Wolfe said that geolocation is relative to Band 0, and that band-to-band registration information is measured by MCST.

Validation and Operational QA of L1B

Bruce Guenther summarized planned validation and operational QA activities for MODIS L1B products. Categories include 10 operational activities, 19 calibration activities, and 19 vicarious activities. These activities will be mapped into radiometric, spectral, spatial, and other validation studies. Regarding QA, Guenther discussed converting radiometric uncertainty into a 4 bit (0-15) scaling index using an exponential scaling function. He reviewed the uncertainty values corresponding to each index value on a band-by-band basis and presented an overview of L1B QA products.

L1B Radiance Validation

Kurt Thome discussed L1B radiance validation. He reviewed the validation process and outlined the field calibration plan that includes on-orbit instrument cross calibration between field campaigns. He said that joint campaigns with other groups would be welcome. The initial QA volume is expected to be four or five scenes over the first several months, ramping up to one scene per day as experience is gained in collecting field data and in training students for field campaign work.

Science System Status

Mike Moore of Earth Science Data and Information System (ESDIS) provided a Science System status update. He said that since the last MODIS Science Team meeting, the Flight Operations System (FOS) has been replaced by Raytheon's EOS Mission Operations System (EMOS). He presented a list of the ECS Release 4 at-launch capabilities and reviewed ingest and archive issues being worked. Database configuration problems prevent some types of searches from working; patches for this are being developed. All fundamental search, order, and distribution requirements defined in the ECS baseline have been verified.

Early Science and Science Outreach

Yoram Kaufman said the Terra outreach team coordinates outreach activities of the PIs through the Executive Committee for Science Outreach (ECSO). David Herring added that the team is establishing an EOS Rapid Response Network and managing the Earth Observatory web site. The Rapid Response Network headed by Jim Collatz, plans to foster rapid turn-around of Terra and Landsat 7 imagery over significant Earth events. They have a verbal agreement with the USGS Center for the Integration of Natural Disaster Information (CINDI) to share information, and will work to produce data visualizations for release to the public media. Herring reviewed the Earth Observatory Web site, found at http://earthobservatory.nasa.gov. Other outreach activities include a partnership with the Smithsonian Institution's American History and Natural History museums, work with the Learning Channel on documentaries on "Fire" and "Ice," and publication of articles in popular magazines. Complementary Web sites include the Terra page at http://www.terra.nasa.gov and the Global Fire Monitoring site at http://modarch.gsfc.nasa.gov/fire_atlas.

MODIS Direct Broadcast Data Level 1 Processing System Status

Daesoo Han reported on the status of the MODIS L1A and L1B Direct Broadcast (DB) system. MODIS direct broadcasting will operate except when the spacecraft is in range of a Deep Space network station. Approximately 1 GB of data will be available per 10-to-12-minute overhead pass. The MODIS DB Ground Team (MDBGT) is providing the source code needed to produce Level 1 and a limited number of Level 2 products. The Release 1 processing system has been tested and is ready for release. Future work includes incorporating MODIS production software changes and adding Level 2 products into the DB system.

NOAA Plans

Gene Legg described NOAA's plans for MODIS data. Their objective is to examine and determine the applicability of EOS Prototype Operational Instruments (POIs) to NOAA's warning and forecasting obligations. NOAA is primarily interested in data from the continental United States and its coastal waters, and will be producing products that correspond to the first 10 PGEs. Data products should be available within 180 minutes of NOAA's receipt of Level 0 data. MODIS data will be reviewed by NOAA data Product Oversight Panels (POPs) with input from the MODIS Science Team before release. Panel approval will be required for the routine release of data products.

MODIS PFM/FM1 Status

Neil Therrien provided a status update for the MODIS PFM and FM1 instruments. The PFM instrument is at the Vandenberg Air Force Base (VAFB) launch facility, and MODIS test equipment is up and running. Spacecraft-level science checks for MODIS have been completed. A thermal vacuum retest is scheduled for mid-May, and the FM1 instrument completion is scheduled for midsummer 1999. Guenther summarized the improvements of FM1 over PFM, including improved polarization measurements and scan-mirror-scatter quality, and the reduction or elimination of light leaks in the system.

Oceans Products Status

Bob Evans reviewed the status of the Oceans science products. Version 2.2 delivery reduces the number of ESDTs from over 2000 to about 160. Science algorithms have been updated, and program efficiency improvements have been made. In particular, improvements made to HDF file utilization resulted in reducing the amount of time spent reading the file from 60 minutes to about 1 minute. The ability to make products now falls within the CPU resources that SDST specified; it is important to get the new Version 2.2 software into the production system. Evans is confident that the Oceans team will be able to produce good products at launch.

MODIS Science at the University of Wisconsin

Paul Menzel discussed the status of MODIS science at the University of

Wisconsin. He reviewed updates to the MODIS cloud mask and summarized collaborative work with Zhengming Wan on surface emissivity and soundings. Menzel presented results from the March 1999 Winter Exercise (WINTEX) field study and a MODIS Vicarious Calibration campaign over the Antarctic Plateau. It is expected that Top of Atmosphere (TOA) accuracies in upwelling radiance over Antarctica should be on the order of 0.05 K. He closed with a summary of MODIS direct broadcast capabilities at Wisconsin; the system should routinely be acquiring data by the end of 1999.

Night-Time Band 36 MODIS Data

Jan-Peter Mueller presented a proposal for a new product, using night-time band 36 data to quantify urbanization. Analyses indicate that MODIS should be able to detect night-time lights at higher spatial resolution and with better radiometric calibration than is possible with the Defense Meteorological Satellite Program-Operational Linescan System (DMSP-OLS). Mueller would like to use the night-time band 36 data early on to determine the feasibility of producing new post-launch products. Guenther commented that taking one orbit's worth of this data every other day should not overload the system, and that some night-time data collections ordinarily would take place for SWIR calibration.

Oceans Summary

Wayne Esaias summarized the Oceans Breakout sessions. He acknowledged tremendous progress in the MODAPS system over the past 6 months and emphasized a need to integrate the Oceans products through Level 3 into the system. Esaias discussed validation plans that include a validation cruise scheduled for off the coast of Mexico from October 1–21. A launch slip would result in no MODIS overflight data to validate. He described planned early science efforts that will focus on iron limitation for ocean production, fluorescence efficiency, and regional phenomena.

MODLAND Summary

Chris Justice summarized the MODLAND breakout sessions. He noted that data system issues dominated the discussions. The Land group will continue prototyping QA data for the n-day test. He suggested that user services coordination is needed. An integrated land schedule has been developed, combining the MODLAND production, QA, and Validation timelines. Justice presented a strawman proposal for Land early products and images, and he listed validation opportunities and resources. He said that closer links with other sensors are needed to perform cross-calibration, validation, and multisensor science. MODLAND suggests an Early Products meeting at about 6 months post-launch to focus on how users can obtain data, product quality, and improvements in the data. A Science Results meeting would follow at about 12 months after launch.

Atmospheres Summary

Michael King chaired the Atmospheres Breakout session. The group discussed mostly data processing and system issues, including the PGE update schedule. PGE55, Clear Sky Radiance (CSR), is still being worked and may not be implemented at launch. This code takes clear scenes from cloud mask and writes the file to granule. It is then integrated into the daily global composite. Time series are used by cloud mask and cloud product to better determine the clear scenes. Although CSR would improve cloud mask, it can run without it. The group considered the contents for an Atmospheres Web site. Suggestions included an overview of products, links to product sites, calendar, staff listings, a bulletin board and image visualization tools, product imagery, and some early sample designs. They talked about parameters for releasing data to the community and how to get data out quickly and accurately.

Closing Remarks

Vince Salomonson closed the plenary session, noting that all topics were well-covered by the discipline groups. He was very supportive and enthusiastic about an early products meeting in the launch +6 month timeframe. After announcing the next meeting would take place near VAFB within 3 days of the Terra launch, Salomonson declared the meeting adjourned.

A Portable Integrating Sphere Source for Radiometric Calibrations from the Visible to the Short-Wave Infrared

— Steven W. Brown (swbrown@nist.gov), and B. Carol Johnson, National Institute of Standards and Technology, Optical Technology Division, Gaithersburg, MD

I. Introduction

The National Aeronautics and Space Administration's (NASA's) Earth Observing System (EOS) Project Science Office has established a program in conjunction with the National Institute of Standards and Technology (NIST) to validate radiance scales of sources at NASA calibration facilities and to establish traceability to national standards maintained at NIST (Butler and Johnson 1996a, b; Butler and Barnes 1998). Under the auspices of this program, several portable transfer radiometers have been built by NIST for NASA to measure radiance in the visible (Johnson et al. 1998a), the short-wave infrared (Brown et al. 1998), and the thermal infrared (Rice and Johnson 1998) wavelength regions. The portable radiometers travel to EOS satellite instrument builder facilities and EOS vicarious calibration facilities in order to measure the radiance of designated sources, often in conjunction with radiometers from other U.S. and international laboratories. The results are then used to validate the radiance scales of the sources and to tie these scales directly to the radiance scale maintained by the national standards laboratory.

Transfer radiometers from various laboratories are often calibrated using different techniques. When they subsequently measure the radiance of a source, results among the instruments vary by approximately 2 % in the visible, increasing to greater than 5 % in the short-wave infrared[1]. We would like to reduce the variance in radiance measurements made with the transfer radiometers. A portable, stable sphere source could be calibrated for spectral radiance at NIST using the Facility for Automated Spectral Irradiance and Radiance Calibrations (FASCAL), the fundamental U.S. facility for radiance calibrations (Walker et al. 1987). Measuring this source with transfer radiometers from NIST and other institutions would validate their radiance responsivity scales and tie them to the national radiance scale maintained at NIST. Using this approach, problems in the radiance responsivity calibrations of the field instruments could potentially be identified and the variability in radiance measurements using different instruments reduced.

Many of the transfer radiometers are filter-based instruments, with filter center wavelengths and bandpasses selected for a specific application, such as for calibrations of sources associated with a particular flight instrument (Johnson et al. 1998a). This type of transfer radiometer can measure the radiance of a source at a finite, limited number of wavelengths with fixed bandpasses. The source radiance at other wavelengths — often important for the calibration facility — is then calculated by interpolation between the radiometer fixed wavelengths. The accuracy of the sphere radiance at intermediate wavelengths derived from filter radiometer measurements therefore depends, in part, on the validity of the interpolation scheme. A stable field source could in principle be used at the calibration facility to validate the radiance of a target source at any wavelength, as long as suitable radiometers were available.

To address these issues, we have designed and built a stable, portable, integrating sphere source. Similar in principle to the SeaWiFS Quality Monitor (Johnson et al. 1998 b), the source was designed to be used at EOS calibration facilities in conjunction with the transfer radiometers over the wavelength range from 400 nm to 2500 nm. Deployment of the source gives us extra flexibility in implementing the EOS radiance validation program. We are now able to include source-based sphere radiance validation measurements in addition to previously established detector-based methods. In this application, it is important that the sphere source maintain a radiance scale traceable to FASCAL in the field. While the monitor detectors provide a measure of the stability of the sphere output over a limited wavelength range, the true stability of the sphere output must be measured at several wavelengths over the spectral range of interest to verify the source radiance stability. Optimal use of the source will therefore require that a reliable, stable, well-characterized radiometer accompany the source to a

[1] Butler, James J., NASA Goddard Space Flight Center, private communication.

particular field site and verify that its radiance did not change upon shipping or upon use in the field.

In its first application, the sphere source was shipped to a field site in Honolulu, Hawaii in support of the Marine Optical Buoy (MOBY) program (Clark et al. 1997). These programs provide in situ measurements of water-leaving radiance for comparison to satellite-derived results. This paper presents a description of the instrument and results of stability measurements of the source radiance both prior to and after its initial deployment.

II. Description

The sphere is 30.5 cm in diameter, with a 10.2 cm exit aperture. Spectralon[2] was chosen for the sphere walls for higher throughput in the short-wave infrared and for stability during shipping. The sphere comes equipped with four, 30-watt, quartz-halogen lamps located at 90-degree intervals around the surface. Baffles are placed between the lamps and the exit aperture of the sphere. Two monitor photodiodes are placed near the bottom of the sphere. The first is a silicon (Si) photodiode equipped with a photopic filter; the second is an indium gallium arsenide (InGaAs) photodiode equipped with a 200-nm bandpass filter centered at 1400 nm. The lamps are wired in series. Each lamp can be individually turned on or off during operation; timers record the total number of operational hours on each lamp.

There are two modules associated with the portable sphere source, as shown in Fig. 1. The integrating sphere source and an interface electronics box are located in the upper module. The lower module contains a second interface electronics box, two digital-to-analog converters (DACs), two calibrated shunt resistors, two digital multimeters (DMMs) and two power supplies. The second shunt resistor, digital multimeter and power supply are redundant; they are included as a safety backup measure. However, they are also designed to be used with standard irradiance lamps. This provides an additional source capability with the instrument for irradiance calibrations and, when used in conjunction with a reference plaque, radiance calibrations.

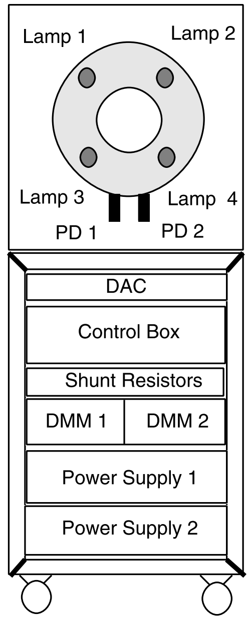


Fig. 1. Schematic diagram of the portable integrating sphere source. PD1 and PD2 refer to the Si and InGaAs monitor photodiodes, respectively.

Lamp connections, timers, ON / OFF switches and photodiode amplifiers are included in the top electronics box. The bottom electronics box supplies power to the source and receives the lamp voltage and photodiode signals from the top box. These signals are then input into a DMM, and read into a computer through the General Purpose Interface Bus (GPIB) interface. In addition, the current to the lamps is monitored by recording the voltage drop across a calibrated shunt resistor. This signal is also input into the DMM and recorded on a computer. The current to the lamps, the voltage drop across each lamp, and the two photodiode signals are automatically recorded in a data file every 10 s, along with the time, whenever the source is turned on.

The source can be operated in two modes, either passively or actively. In the passive control mode, the power supply current is set through the GPIB bus and subsequently monitored for stability. In the active control mode, the power supply current is remotely controlled by an external voltage. In this mode, the voltage to the power supply is continuously updated to maintain a constant voltage drop across the calibrated shunt resistor, thus stabilizing the current supplied to the lamps. The two twelve-bit DACs and a voltage divider provide the control voltage to the power supply. The total resolution of the external voltage control signal is greater than 16 bits, enabling the current from the power supply to be set with very high precision. At the moment, the source is operated under passive control.

III. Operation

The sphere radiance, measured with the Visible Transfer Radiometer (VXR), is shown in Fig. 2 for lamp combinations ranging from all lamps on to one lamp on. The data are given by symbols; the solid lines are cubic spline fits to those data. One of the primary functions of the measurement assurance program is to validate measurements made by calibration laboratories involved in calibrating the spectral response of sensors developed as part of EOS. We designed the sphere radiance to be comparable to radiance

[2] Identification of commercial equipment does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment identified is necessarily the best available for the purpose.

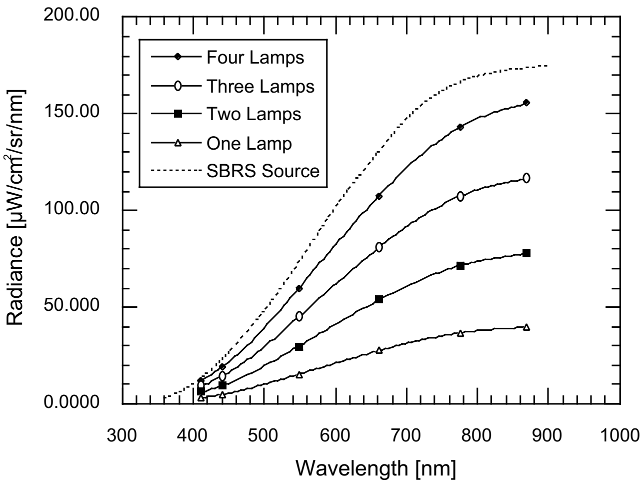


Fig. 2. Sphere radiance measured with the VXR for all four lamp levels. The dashed line is the maximum radiance of the SBRS source used to calibrate MODIS.

levels of those calibration sources. For example, the dotted line in Fig. 2 is the maximum level radiance from the sphere source at Raytheon Santa Barbara Remote Sensing. This source was used to calibrate the radiance responsivity of the Moderate Resolution Imaging Spectroradiometer (MODIS), currently scheduled to be launched on Terra (formerly AM-1), the first of several satellites to be deployed over the 18-year life of the EOS mission.

In Fig. 3, we show the operational characteristics of the source over the course of an hour as lamps were gradually turned off. Single lamps were turned off after 20 min, 31 min, and 42 min. In Fig. 3 (a), we show the change in lamp current, measured as a voltage drop across the calibrated shunt resistor. With the exception of small changes of short duration (shown by the arrows), the lamp current was stable as lamps were turned off. The lamp current decreased by approximately 0.03 % over the first 10 min of operation, then continued to decrease slightly (on the order of 0.01 %) over the next 50 min.

The two monitor photodiode signals — shown in Figs. 3 (b) and (c) — showed very different behaviors. The Si monitor photodiode signal was several times more stable than the IGA monitor photodiode signal. The Si monitor photodiode signal changed on the order of 0.5 % over the first 20 min (four-lamp level), then remained stable to within 0.1 % over the next 40 min (Fig. 3 (b)). On the other hand, over the first 20 min (4 lamp level), the InGaAs monitor photodiode signal changed by over 2 % (Fig. 3 (c)). As the second and third lamps were turned off, the InGaAs signal continued

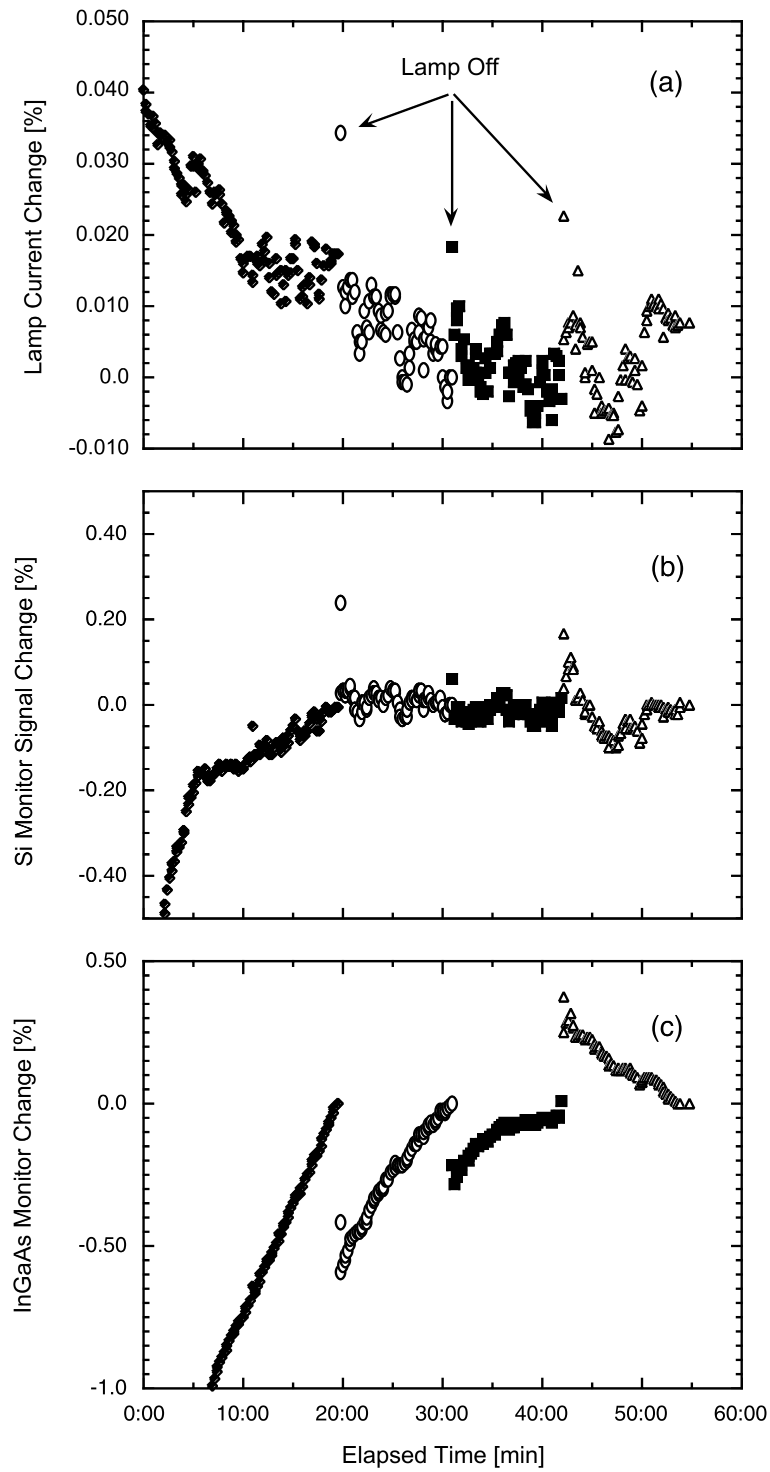


Fig. 3. Change in (a) the lamp current, (b) the Si monitor photodiode signal, and (c) the InGaAs monitor photodiode signal over the course of an hour as individual lamps were turned off. (◆) Four lamp level; (o) three lamp level; (■) two lamp level; (Δ) one lamp level. The Si and InGaAs photodiode signals were normalized to their values at the end of each lamp sequence.

to increase with time: approximately 0.5 % over the next 10 min (3 lamp level), and 0.3 % for the following 10 min (2 lamp level). During the next 10 min (1 lamp level) the signal decreased on the order of 0.4 %. Because the radiant power emitted from quartz-halogen lamps is typically less sensitive to changes in the lamp current in the short-wave infrared than in the visible or ultraviolet wavelength ranges, they are often more stable in the short-wave infrared than in the visible (Early and Thompson 1996). Consequently, these results may indicate a stability problem with the InGaAs monitor detector rather than an instability in the sphere output in the short-wave infrared.

To verify this hypothesis, we measured the sphere radiance at 1500 nm (4-lamp level) with the Short-Wave Infrared Transfer Radiometer (SWIXR) (Brown et al. 1998) and compared the results with the InGaAs monitor data. After a 10 min warm-up, the InGaAs monitor signal increased by 0.6 % over the subsequent 5 mins, while the SWIXR signal increased by 0.06 %. One source of instability in the InGaAs monitor signal was thought to be the filter selection. We had a filter in front of the InGaAs photodiode that included the 1380 nm wavelength region – a known wavelength region of instability in sphere sources arising from water absorption in the sphere. The filter was replaced with one centered at a wavelength of 1540 nm, with a FWHM bandwidth of 20 nm. The measurements were then repeated, and, as expected, the change in the InGaAs monitor diode signal decreased — by a factor of three. The signal change remains larger than expected, however, and additional work is required to identify the source of the instability in the InGaAs monitor diode output.

The VXR measured the sphere radiance continuously for 5 min for each lamp level, starting at elapsed times of 15 min (4 lamp level), 25 min (3 lamp level), 36 min (2 lamp level), and 47 min (1 lamp level). The data from all six channels showed similar trends over the five-minute acquisition times. As expected, the sphere was more stable at longer wavelengths. This is illustrated in Fig. 4 for lamp levels three and four; the standard deviation of the individual radiance measurements continuously decreased as the measurement wavelength increased.

As discussed in Early and Thompson (1996), changes in the lamp current are reflected in the sphere radiance. The slight changes in the lamp current shown in Fig. 3 (a) are also seen in the Si monitor photodiode signal (Fig. 3 (b)) and in the VXR measurements. Consequently, the slight temporal variations in the current supplied to the lamps contribute to uncertainties in the sphere radiance. Since we are currently operating the system in the passive mode, the short-term fluctuations in the sphere radiance can potentially be reduced through active control of the current to the lamps. However, relative uncertainties on the order of 0.05 % or less (Fig. 4) are much less than the uncertainty in the sphere radiance as determined by FASCAL[3] (Barnes et al. 1998), and much less than the uncertainties currently required for EOS sensors such as MODIS (Barnes et al. 1998). Thus, an additional radiance uncertainty on the order of 0.05 % or less arising from slight changes in the current supplied to the lamps will not noticeably increase the overall uncertainty of the sphere radiance. Based on the measurements of the voltage drop across the shunt resistor and the Si monitor diode, a 10-min warm-up time prior to data acquisition is sufficient for most applications.

To determine the repeatability of the instrument, the sphere radiance was first measured with the VXR (for all four levels); then the system was turned off. After a short wait, the system was turned back on and the radiance again measured. The VXR remained stationary during these measurements. The sphere radiance repeated for all lamp levels to within 0.1 %; for most levels, the radiance values agreed with each other to within 0.05 %. To test the system reproducibility, the radiance was measured with the VXR one

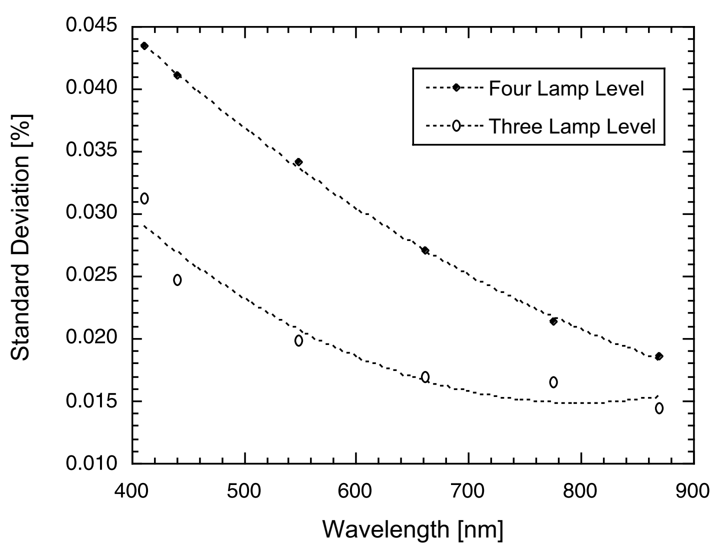


Fig. 4. Standard deviation of measurements of the sphere radiance at six wavelengths taken with the VXR for the four-lamp level and the three-lamp level. The acquisition time was 5 min for each channel.

[3] The expanded uncertainties (*k*=2) in spectral radiance for this type of sphere source measured by FASCAL is approximately 1 % at 400 nm, decreasing to 0.5 % at 900 nm.

day, and the system turned off. The sphere source and the VXR were subsequently moved to a different location. The following day, the instrumentation was turned on, the VXR again aligned to measure the central region of the sphere aperture, and the sphere radiance measured. As shown in Fig. 5, the sphere radiance measured on the two subsequent days repeated to within approximately 0.1%.

Based on these measurements, we concluded that the system was stable and the radiance reproducible in the short term. We next wanted to test the stability of the source upon shipping the instrument to the MOBY field site. The sphere radiance was measured by the VXR prior to shipping and immediately upon its return to NIST.

The calibration facility at the MOBY site is not sealed from the atmosphere, and measurements were often made after sunset. During the measurements, a number of small bugs entered the sphere and thereupon expired — most likely from the extreme thermal environment they encountered. Upon return to NIST, those bugs remained in the bottom of the sphere. The VXR initially measured the sphere radiance with the bugs remaining in the sphere. The sphere was then carefully and literally debugged, and the radiance again measured. As shown in the insert in Fig. 6, the bugs caused a slight decrease in the sphere radiance – approximately 0.5 % from 600 nm to 900 nm, increasing to 0.75 % at 411 nm. After debugging, sphere radiance measurements before and after the MOBY site visit agreed on average to within 0.05 % for the VXR channels ranging from 440 nm to 780 nm (Fig. 6). At 411 nm, the sphere radiance measured after MOBY had decreased by approximately 0.5 % over the radiance measured prior to the site visit, while at

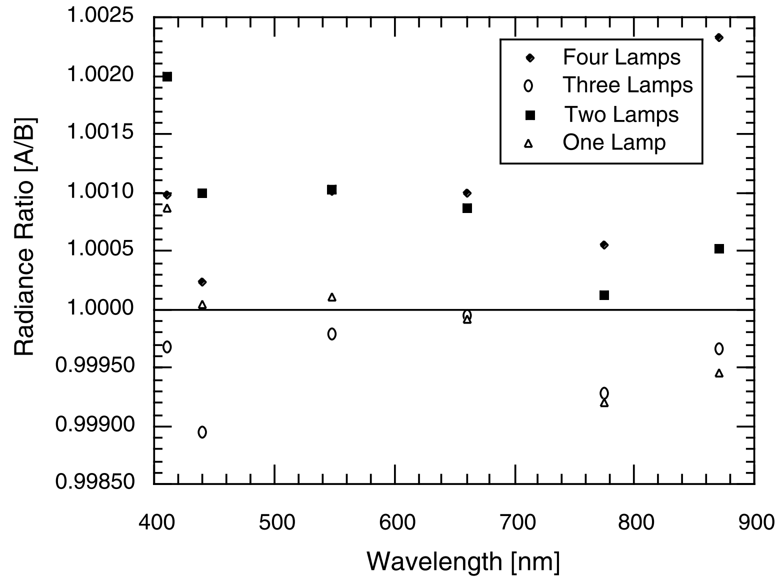


Fig. 5. Ratio of radiance measurements taken with the VXR on two different days, A and B.

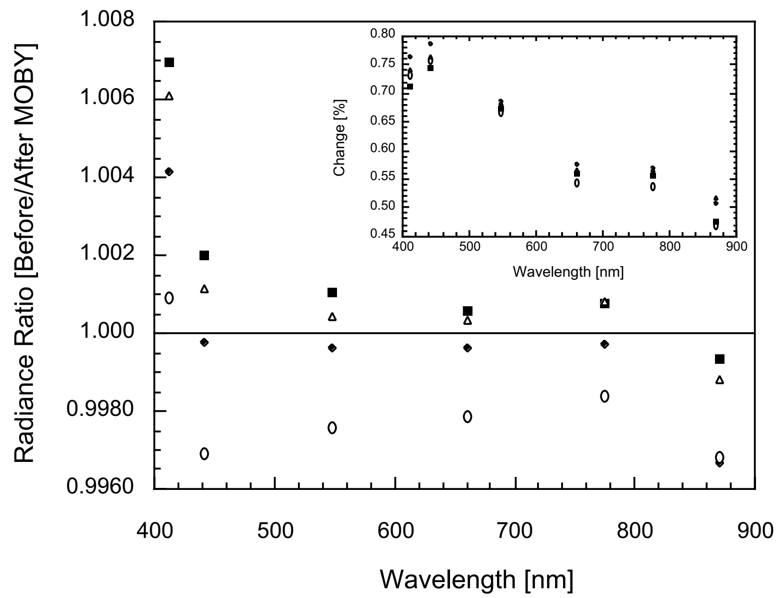


Fig. 6. Ratio of sphere radiance measurements with the VXR prior to and after (debugged) the trip to the MOBY field site. Inset: Radiance change upon debugging the sphere. (◆) Four lamp level; (o) three lamp level; (■) two lamp level; (Δ) one lamp level.

870 nm the average sphere radiance had increased by 0.2 %. For comparison, the silicon monitor photodiode signal for the four lamp levels changed by –0.15 %, -0.23 %, +0.11 %, and +0.06 %, respectively. These data correlate well with changes in the sphere radiance measured by the VXR at 550 nm.

IV. Summary

In summary, we have developed a portable integrating sphere source to complement existing measurement capabilities used to validate the radiance of sources at EOS calibration facilities. The source was designed to operate in the radiance range used to calibrate EOS satellite sensors such as MODIS. At 550 nm, for example, the source radiance ranges from approximately 50 μW / cm^2 / sr / nm at the four-lamp level down to approximately 10 μW / cm^2 / sr / nm for the one-lamp level. The source radiance is repeatable to within 0.1 % in the short term. After shipping the instrument to Hawaii, using it in the field, shipping it back and debugging it, the sphere radiance as measured by the VXR decreased slightly — approximately 0.5 % — at 411 nm and increased slightly — approximately 0.2 % — at 870 nm. The radiance did not noticeably change at the other measured wavelengths. The Si monitor diode seems to accurately reflect the radiance level in the visible wavelength range, though it exhibits decreased sensitivity to sphere radiance changes at 411 nm and at 441 nm.

The InGaAs monitor diode is not stable enough for our measurement purposes, and it will be modified to improve the stability. Also, the sphere source's radiance and operating characteristics in the short-wave infrared need to be evaluated, along with the radiance uniformity within the exit aperture. It is next scheduled to travel with the portable transfer radiometers to NASA's Ames Research Center to validate the radiance of a sphere source used to calibrate optical sensors that are deployed from aircraft, such as the MODIS Airborne Simulator (MAS) (King et al. 1986).

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Continued from page 3)

AMSR Science Team Meeting

Greenland. Further details about this campaign can be obtained from Professor Gudmansen at pg@emi.dtu.dk <mailto:pg@emi.dtu.dk>.

Before adjourning, we briefly discussed AMSR-E public outreach. A web site and / or a brochure outlining the benefits of the AMSR-E data will be available shortly.

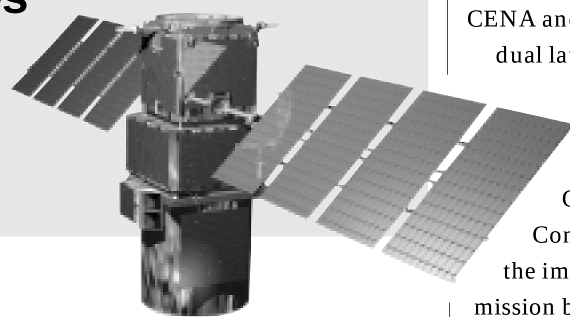
The next Joint AMSR Science team meeting is planned for 6 and 7 July, in Oklahoma City, Oklahoma.

Acronym list:

AMR	airborne microwave radiometer
AMSR	advanced microwave-scanning radiometer for ADEOS-II
AMSR-E	advanced microwave-scanning radiometer for EOS
AMSS	advanced multi-spectral scanner
AVIRIS	airborne visible and infrared imaging spectrometer
EOSD	earth observation system development
GAME	GEWEX Asian monsoon experiment
GEWEX	global energy and water cycle experiment
GRASP	Greenland Arctic Ocean shelf project
GTS	global telecommunications system
IOP	intense operating period
MICRORAD	microwave radiometry and remote sensing of the environment
NASDA	national aeronautics and space administration of Japan
PSR	polarimetric scanning radiometer
SAR	synthetic aperture radar
SGP	Southern great plains
SSM / I	special sensor microwave / imager
TMI	TRMM microwave imager
TRMM	tropical rainfall measuring mission (U.S.-Japan)

The First PICASSO-CENA Science Team Meeting Minutes May 18-19, 1999

— Lelia Vann (l.b.vann@larc.nasa.gov), Acting PICASSO-CENA Science Manager, Langley Research Center



The first post-selection Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations-Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) science team meeting was conducted at the Radisson Hotel in Hampton, VA, on May 18-19. Dave Winker, the PICASSO-CENA Principal Investigator (PI) from Langley Research Center (LaRC), welcomed all participants, briefly reviewed the agenda, and noted that all 21 PICASSO-CENA science team members were present.

[See related article by Winker on page 22]

Day 1

Ann Carlson, the Acting Assistant Director for Atmospheric Sciences at LaRC, gave a special welcome to our French partners and our CloudSat partners. Ann noted the hard work previously performed by the PICASSO-CENA proposal team that resulted in the winning proposal and was confident that the same hard work would result in a successful mission.

Jim Garvin, the ESSP Project Scientist at Goddard Space Flight Center (GSFC), delivered his perspective of the PICASSO-CENA mission. He stated that PICASSO-CENA offers revolutionary science associated with the role of aerosols in the Earth's radiation budget, and that our challenge will be to preserve the baseline measurements under the realities of space-hardware development. Speaking from lessons learned about previous missions, he urged us to strategize early about science relaxation and descope plans. He advised the PICASSO-CENA science team to re-examine the minimum science requirements and consider relaxing spacecraft requirements before deselecting science instruments or derating instrument performance. Jim stressed the importance of developing calibration and validation strategies early in the program. He recommended defining aircraft and/or correlative spacecraft measurements as soon as possible. Because the ultimate deliverable is valuable science data, early release of preliminary data is desirable and can assist in developing outreach goals as well as implementing the Science and Data Analysis Program (SDAP). The SDAP will set aside approximately 10% of the mission cost for peer-reviewed investigations using PICASSO-CENA data products. Jim's final thoughts were on the challenges associated with the laser system in spite of the recent successful bench testing. He encouraged an airborne simulation of the PICASSO-CENA lidar performance. He also offered strategies for optimizing sampling versus instrument lifetime. Bob Curran, the NASA Headquarters PICASSO-CENA point of contact, shared his excitement about the PICASSO-CENA mission and flying lidars in space for atmospheric remote sensing. He was also pleased to announce that PICASSO-CENA and CloudSat were targeted for a dual launch scheduled early in 2003 to fly in formation with EOS PM-1. Lastly, he requested support from the PICASSO-CENA team in convincing both Congress and the general public of the importance of the PICASSO-CENA mission by clarifying the importance of the measurements obtained.

Dave Winker stepped through the science portion of the proposal, beginning with the mission concept, then proceeding to the science objectives and requirements flowdown. He presented examples of LITE approaches and measurements where appropriate for clarification. Dave discussed the descope plan that was presented in the proposal. He emphasized that we are not locked into the minimum mission defined in the proposal, but that we do need to solidify the minimum mission by the end of the calendar year. Dave provided a definition, an approach, and an example of the Vegetation Canopy Lidar (VCL) Descope Options.

Debbie Carraway, the PICASSO-CENA Project Manager at LaRC, gave the PICASSO-CENA project overview and status. She pointed out the major milestones and their corresponding dates. The most critical event is the Mission Confirmation Review (MCR), scheduled for July 2000. The MCR is basically the "go/no go" decision point of the mission. Debbie highlighted the following two documents as deliverables from the science team in February 2000: "Descope Plan" and "Science and Mission Requirements Document (SMRD)." An example outline of the VCL SMRD was presented.

Pat McCormick, a PICASSO-CENA Co-Principal Investigator (Co-PI) from Hampton University (HU), gave an overview of several specific HU activities: an International Science Advisory Panel (ISAP), algorithm implementation, outreach, and validation. Pat has established a 7-member ISAP to broaden scientific oversight, expand the usefulness and application of the data products, and provide a vehicle for broad international collaboration. Dianne Robinson presented a variety of activities being planned for the outreach program. A sunphotometer, the graphing calculator, and a web-site contest were just a few suggested activities that are being proposed.

Jacques Pelon, a PICASSO-CENA Co-PI from the Institut Pierre Simon Laplace in France, presented the French science organization and activities. Currently, there are three focused working groups: Climate and Chemistry Modeling, Cloud Properties and Climatology, and Aerosol Properties and Climatology. Each working group is led by one of the French PICASSO-CENA science team members. Jacques presented future validation plans as well.

John Stadler, the PICASSO-CENA Systems Engineer from LaRC, delivered the mission overview including the instrument descriptions, payload overview, PROTEUS spacecraft bus, PICASSO-CENA satellite, formation-flying strategy, and the resource margins.

Mary Beth Wusk, the PICASSO-CENA Mission Operations Manager from LaRC / G&A Technical Software, presented the mission operations concept. The satellite utilizes both the S-band and X-band for communications. The S-band is used for both command and telemetry of spacecraft and instrument critical data, and S-band data are transferred to NASA four times a day. The X-band is used for the science data telemetry and data are transferred within 48 hours.

Chris Hostetler, a PICASSO-CENA Co-I at LaRC, presented the Aircraft Validation Unit (AVU) objectives and status. The AVU consists of an aircraft-based oxygen A-band spectrometer (ABS) and a lidar. A decision on making the AVU polarization sensitive or insensitive will be made by the end of May from technical and cost analyses being conducted by Ball. The near-term schedule was shown and indicates data acquisition beginning in February 2000, with data available to support the MCR in August 2000.

Dave Winker presented the data products contained in the Step 2 proposal and talked about utilizing Algorithm Theoretical Basis Documents (ATBDs) to describe the algorithms, data handling and processing, software interfaces, and processing requirements used in generating these data products. He compared a simple data flow from telemetry to Level 2 products with that envisioned for PICASSO-CENA.

He also presented the science team organization and identified working groups for major retrieval algorithms. The primary working groups are: Lidar, A-Band Spectrometer (ABS) / Wide Field Camera (WFC), Imaging Infrared Radiometer (IIR), and Fluxes. Other teams that might generate joint data products with the PICASSO-CENA and CloudSat teams are being considered. In addition, an outline of a generic ATBD was provided. Each working group is responsible for generating its corresponding section of the ATBD.

Chris Currey, the PICASSO-CENA Science Data Manager at LaRC, presented the data management system overview including the DAAC interface, system sizing, organization, and near-term plans. He stressed the importance of defining interfaces early and working as a team with the science working groups, HU, mission operations, and the DAAC to reach common scientific goals. Chris introduced the spiral model concept of the software development life cycle for science data products. This concept uses an incremental build and test approach as the requirements are developed and validated. The data-management schedule presented showed operational code running on the DAAC by September 2002.

Bob Charlson, a PICASSO-CENA Co-I from the University of Washington, restated the first PICASSO-CENA science objective from the proposal and identified what type of information was needed to estimate direct aerosol “forcing” and its uncertainty. He stated that there is a need to distinguish between natural and anthropogenic forcing. This can only be done with a set of *in situ* aerosol measurements to yield the chemical composition, optical properties, and microphysical properties. He presented an example of an autocorrelation versus lag distance to obtain an indication of how often to sample and how close *in situ* measurements need to be to the mission measurements to be useful for estimating radiative forcing. There is a tradeoff between spatial offset and sampling duration that needs to be characterized for adequate aerosol forcing determination.

Graeme Stephens, a PICASSO-CENA Co-I and the CloudSat PI from the Colorado State University, gave the CloudSat mission overview showing the tight formation flying with PICASSO-CENA for coincident lidar-radar profile information and coincident EOS PM-1 information for

(Continued on page 25)

Global Observations Of Aerosols And Clouds From Combined Lidar And Passive Instruments To Improve Radiation Budget And Climate Studies

— David M. Winker (d.m.winker@larc.nasa.gov), NASA Langley Research Center

1. Introduction

Current uncertainties in the effects of clouds and aerosols on the Earth radiation budget limit our understanding of the climate system and the potential for global climate change. Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations - Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) is a recently approved satellite mission within NASA's Earth System Science Pathfinder (ESSP) program which will address these uncertainties with a unique suite of active and passive instruments.

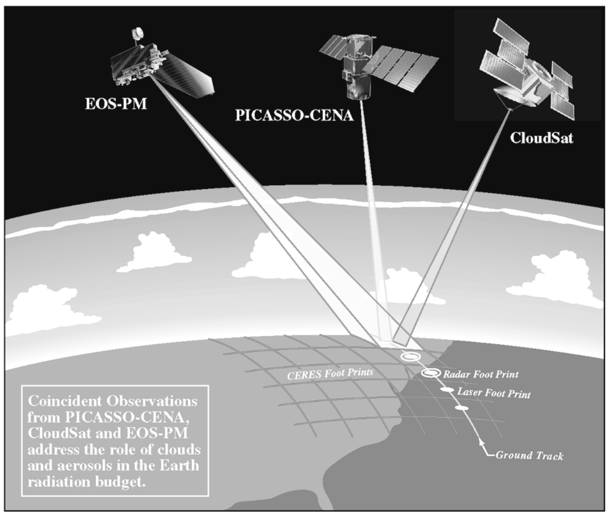


Figure 1. PICASSO-CENA flies in formation with EOS PM-1 to obtain greater value data than obtainable from either mission alone. In addition, the recently selected CloudSat will be flying in formation with PICASSO-CENA which will greatly enhance the data collected. This unique 3-year coincident global set of data on aerosol and cloud properties, radiative fluxes, and atmospheric state enables new observationally based assessments of the radiative effects of aerosol and clouds. This information will greatly improve our ability to predict future climate change.

[See also related article by Vann on page 20]

The Lidar In-space Technology Experiment (LITE) demonstrated the potential benefits of space lidar for studies of clouds and aerosols (Winker et al., 1996). PICASSO-CENA builds on this experience with a payload consisting of a two-wavelength polarization-sensitive lidar, an oxygen A-band spectrometer (ABS), an imaging infrared radiometer (IIR), and a wide-field camera (WFC). Data from these instruments will be used to measure the vertical distributions of aerosols and clouds in the atmosphere, as well as optical and physical properties of aerosols and clouds which influence the Earth radiation budget.

PICASSO-CENA will be flown in formation with the EOS PM satellite and with the recently selected CloudSat to provide a comprehensive suite of coincident measurements of atmospheric state, aerosol and cloud optical properties, and radiative fluxes. The mission will address critical uncertainties in the direct radiative forcing of aerosols and clouds as well as aerosol influences on cloud radiative properties and cloud-climate radiation feedbacks (Figure 1).

PICASSO-CENA is planned for a three-year mission, with launch in early 2003. PICASSO-CENA is being developed within the framework of a collaboration between NASA and CNES.

2. Science Objectives

Atmospheric aerosols *directly* affect the Earth's energy balance by absorbing and scattering shortwave (SW) solar radiation, and by absorbing and emitting longwave (LW) infrared radiation. Aerosols *indirectly* affect this balance by modifying the reflectance and lifetime of clouds through their role as cloud condensation nuclei, but this indirect forcing is poorly quantified. Unlike greenhouse gases, tropospheric aerosols are highly variable in space and time due to variable sources and short atmospheric residence times. Thus their radiative effects are also highly variable. The uncertainties in these effects may be more than half the entire greenhouse gas effect, but of opposite sign (Kiehl and Brieglieb, 1993; Jones and Slingo, 1996).

Currently, aerosol forcing estimates are based on calculations using chemical transport models (CTMs). Large uncertainties in the estimated direct aerosol forcing are due to the fact that many of the input parameters are not well known. Additionally, there are no existing global observations of aerosol direct forcing, aerosol properties, or aerosol source strengths against which these model estimates may be checked. Future EOS missions include instruments which will improve current satellite aerosol observations. However, EOS capabilities are not sufficient to allow accurate, measurement-based estimates of aerosol direct forcing. Understanding the Earth radiation budget requires observations of radiative fluxes at the top of the atmosphere (TOA), at the surface of the Earth, and at levels within the atmosphere. Cloud imager and CERES broadband radiation observations from EOS PM will provide estimates of TOA fluxes to an accuracy approaching 1.5 W/m^2 for monthly zonal and global means (Wielicki et al. 1995). However, uncertainties in estimates of mean radiative fluxes at the Earth's surface will be much larger, primarily due to the limitations of passive sensors in characterizing the vertical distribution of multilayer clouds.

Improved representations of cloud processes in models are also required in order to decrease uncertainties in cloud-radiation interactions. The fundamental problem is in modeling the cloud feedback loop. The largest uncertainties involve the use of models to: (a) predict cloud properties based on atmospheric state, and (b) to use these cloud properties to calculate radiative-energy fluxes.

Nearly simultaneous observations of all three parts of the cloud feedback loop are necessary to accurately predict the future impact of greenhouse gases. Near-simultaneity is required because of the short time scales and nonlinear relationships typical of cloud processes. The ability of cloud models to reproduce feedback physics cannot be adequately tested with observations that are decoupled in space and time.

3. Instruments

To address these issues in a cost-effective manner, a payload consisting of four co-aligned, nadir-viewing instruments has been defined:

◊ A two-wavelength, polarization-sensitive lidar providing high-resolution vertical profiles of aerosol and cloud properties. The change in backscatter with wavelength allows a classification of aerosol size. The ratio of orthogonally polarized components of the 532-nm backscatter allows the identification of cloud ice/water phase.

◊ An oxygen A-band Spectrometer (ABS) having sufficient spectral resolution (0.5 cm^{-1}) to resolve the line structure of the oxygen A-band (centered at 765 nm). ABS spectra combined with lidar profile data are combined to retrieve aerosol and cloud optical depth, aerosol absorption, and cirrus asymmetry parameter (Stephens and Heidinger, 1999).

◊ An Imaging Infrared Radiometer (IIR) providing calibrated radiances at 10.5 µm and 12 µm over a 40-km swath. These two wavelengths are chosen to optimize joint lidar/IIR retrievals of cirrus emissivity and particle size.

◊ A Wide Field Camera (WFC) covering the 620-nm-to-670-nm spectral region providing images of a 25-km swath with a spatial resolution of 125 meters. The WFC provides meteorological context and highly accurate spatial registration between PICASSO-CENA and EOS-PM.

The data products to be derived from PICASSO-CENA are summarized in Table 1. Level 2b products involve more complex algorithms than Level 2a and will require a longer period of validation before being made available for distribution.

Table 1. PICASSO-CENA science data products.

Data Level	Data Products
1	lidar browse images, calibrated lidar profiles, calibrated ABS and IIR radiances, uncalibrated WFC images
2a	lidar backscatter profiles, aerosol and cloud height/thickness, aerosol extinction profiles/optical depth, cloud extinction profiles/optical depth, cloud ice/water phase
2b	aerosol single-scattering albedo ice-particle size, cloud-layer emissivity, cirrus asymmetry parameter, surface and atmospheric radiative fluxes

4. Observing Strategy

The PICASSO-CENA orbit was chosen to provide space-time coincidence with EOS PM observations. EOS PM is in a sun-synchronous 705-km circular orbit with an ascending node equatorial crossing time of 13:30 local time. PICASSO-CENA will fly at the same altitude as EOS PM, and its orbit will be maintained so that a point on the ground will be observed by the two platforms within 6 min of each other.

The inclination of the PICASSO-CENA orbit differs slightly from that of EOS PM, so that over the course of the 3-year mission, PICASSO-CENA will slowly precess across the viewing swath of AIRS, CERES, and MODIS. Coincident observations—allowing an assessment of viewing-angle biases in EOS PM retrievals—will be obtained for all seasons and atmospheric conditions.

5. Measurement Objectives

5.1 Aerosols

The single most important advance that PICASSO-CENA provides is a high sensitivity to aerosols, even over bright and heterogeneous land surfaces and under other conditions which are difficult or impossible for passive sensors, such as above clouds or beneath thin cirrus.

Lidar provides high sensitivity to aerosol, but retrievals of t_a involve uncertainties on the order of 30%. This is sufficiently accurate at low optical depths, but at higher optical depths ($t_a > 0.04$) joint lidar-ABS retrievals provide a significant improvement over the retrievals from either MODIS or from lidar alone.

Simultaneous observation of aerosol properties by PICASSO-CENA and of radiative fluxes and atmospheric state from EOS PM will provide direct measurements of aerosol forcing and the key parameters that control it. PICASSO-CENA will provide: (1) vertical distribution of aerosols; (2) two-wavelength aerosol backscatter measurements for classification of aerosol size; (3) aerosol optical depth; (4) aerosol single-scatter albedo; and (5) aerosol source strength, an essential input to CTMs used to assess aerosol radiative forcing.

Further, PICASSO-CENA will allow improved assessments of aerosol indirect forcing through greatly improved aerosol measurements as well as by unambiguously distinguishing clouds embedded in an aerosol layer from those located above or below the layer.

5.2 Clouds

The spatial overlap of multilayered clouds —which comprise over half of all surface observations—represents the largest uncertainty in determining downward LW radiative fluxes at the surface and in estimating LW radiative heating in the atmosphere. Calculated heating rates differ by as much as 30% of the typical zonal-mean LW heating rate of -2 K / day, and the resulting uncertainties in regional monthly mean surface LW fluxes are as high as 20 W / m^2. All current satellite cloud retrievals detect only an upper cloud layer or retrieve one equivalent cloud layer. Improved estimates of surface LW fluxes and atmospheric heating rates will be obtained by combining CERES TOA flux measurements with coincident observations of multilayered clouds from PICASSO-CENA.

Secondly, PICASSO-CENA provides new measurement capabilities which, when combined with EOS PM observations, will allow a far more complete closure of the feedback loop than possible using EOS PM alone. EOS PM will provide atmospheric state information and TOA radiative fluxes, and PICASSO-CENA will provide coincident information on cloud altitude, thickness, and optical and microphysical properties. These new measurement capabilities from PICASSO-CENA will enable significant progress in our understanding of cloud-radiation feedback mechanisms:

◊ The first measurements of ice-cloud asymmetry parameter from a combination of the PICASSO-CENA lidar and ABS. These measurements will provide critical information on the relationship between cloud optical depth and cloud reflectance.

◊ PICASSO-CENA observations of optically thin clouds such as subvisual cirrus and jet contrails will be combined with simultaneous CERES TOA radiative fluxes to evaluate the radiative forcing of optically thin clouds as a function of cloud properties.

◊ For the same amount of condensed water, ice crystals and supercooled water droplets alter radiative fluxes in significantly different ways. Lidar depolarization measurements will provide the first spaceborne vertical profiles of cloud-particle phase and improve our understanding of the radiative influence of mixed-phase clouds.

6. Summary

The comprehensive combined data set to be acquired by PICASSO-CENA and EOS PM will allow fundamental scientific advances in our understanding of the links between aerosols, clouds, and radiation necessary to accurately assess future climate change. Realizing this potential will require careful coordination with supporting modeling and correlative measurement efforts.

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(Continued from page 21)

The First PICASSO-CENA Science Team Meeting Minutes

unique overlap of data for studying clouds. Graeme emphasized the need for identifying joint activities early and suggested organizing a "tiger team" now to address these areas. Several areas for considerations are A-band redundancy, algorithm development, validation, etc.

He gave an A-band tutorial on the second day. He stated that using absorbing and non-absorbing bands within the A-band to measure the abundance of oxygen to infer surface pressure within a 0.5-mbar accuracy has been done. He walked through the clear-air problem and then introduced the atmospheric scattering problem. Graeme discussed the basic question of separating the atmospheric scattering from surface reflection. He also introduced the complexity of 3D effects and addressed when 3D effects invalidate the retrieval. Graeme provided two papers that are to appear in *Journal of the Atmospheric Sciences* (1999).

Deb Vane, the CloudSat Deputy PI from JPL, presented some obvious discussion topics for a dual launch, joint mission, and other science-related topics. She stressed the importance of making a decision soon regarding the A-band instrument redundancy.

The second day began with presentations of the retrieval algorithms for the Infrared Imager Radiometer (IIR), the A-band Spectrometer (ABS), and the lidar.

Jacques Pelon presented ice-crystal size and cirrus-effective-emissivity retrieval using two IIR channels and a cirrus radiation scheme that uses the ratio of the two channels.

Dave Winker presented a top-level schedule of the science team activities and how they are phased to the mission milestones. From this schedule, it becomes clear that preliminary algorithms need to be defined and provided by each working group for Level 1 and Level 2 production coding to begin by July 2000. As mentioned previously, each working group is expected to provide algorithms from which production code can be written and tested.

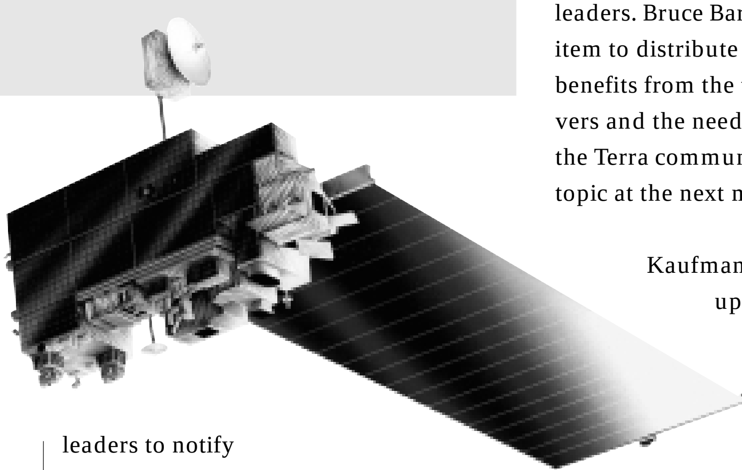
He also proposed to submit a high-level mission-concept paper to the *Bulletin of the American Meteorological Society* (BAMS) this summer / fall and an instrument paper(s) to BAMS after the PDR in early 2001. A technical splinter session with CloudSat and PICASSO-CENA project personnel was held resulting in a number of agreements, issues, and action items. The next (second) science team meeting will be held this fall (the November timeframe) and the third science team meeting will be held next May or July.

The lidar working group leader, Chris Hostetler, provided an example of the types of activities that would be required of the lidar working group as a demonstration of typical activities that may be required of the other working groups. The ultimate deliverable from each working group is an algorithm theoretical basis document (ATBD) from which the Level 1 and Level 2 processing code can be developed. A draft of the ATBD is targeted in support of the Preliminary Design Review (PDR) that is currently scheduled for June 2000.

Other related activities were presented by Ray Hoff, Co-I from the University of Maryland-Baltimore Campus, and by Jim Coakley, Co-I from Oregon State University. Ray Hoff utilized LITE backscattering data to compare with results from the Northern Aerosol Regional Climate Model (NARCM). The model was not entirely complete, but preliminary results agreed quite well. Jim Coakley presented lessons learned from the Indian Ocean Experiment (INDOEX).

Summary of the Mini-SWAMP Meeting

— David Herring (dherring@climate.gsfc.nasa.gov), Science Systems & Applications, Inc.
— Yoram Kaufman, Terra Project Scientist, NASA Goddard Space Flight Center



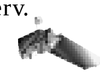
The Science Working Group for the AM Platform (SWAMP) convened twice during the EOS-IWG, held June 15-17 in Vail, CO. The purpose of these "mini-SWAMP" meetings was to discuss the latest information regarding Terra's (formerly EOS AM-1) launch timeline and flight operations, as well as tentative plans for the first public presentation of Terra images. The meetings were chaired by Yoram Kaufman, with David Herring taking the minutes.

The ASTER team reported that the Japanese Ministry of International Trade and Industry (MITI) prefers to release ASTER's first images as soon as possible after it acquires data—within 27 to 40 days after launch. Earlier in the planning process, the Terra strategy was to wait and jointly release the first images from all five instruments simultaneously during a press conference at NASA Headquarters 70 to 80 days after launch. David Herring took an action item to organize a follow-up teleconference with representatives from all instrument teams to discuss this issue and agree upon a platform-wide strategy.

Kaufman said principal investigators must soon begin thinking about and organizing special issues in scientific journals focused on the Terra mission research objectives. He asked the Terra instrument team leaders to notify him within two weeks which conferences and/or special issues they plan to organize for the Terra team. Kaufman stated that the special issues/conferences could be discipline-specific, but that each should be open to all instrument teams. It was tentatively agreed that Vince Salomonson would coordinate an IGARSS special issue; Anne Kahle would take the lead for American Geological Society (AGS); and Jon Ranson will coordinate Terra special issues activities to ensure that there is a good balance of events and information exchange.

Regarding Terra flight operations, Francesco Bordi took an action item to send to all instrument principal investigators a recommended strategy for implementing on-orbit spacecraft maneuvers, as well as an update on present plans for maneuvers based on the current launch date. The Terra team members are to send their comments to Bordi within two weeks after receipt of his recommendations. Jim Drummond proposed developing an ongoing strategy for the routine exchange of information with the instrument team leaders and, in particular, providing them advance warning of new events and/or plans that impact on-orbit operations in the first 50 days after launch. Herring took an action item to identify someone to routinely send these updates to the team leaders. Bruce Barkstrom took an action item to distribute an explanation of the benefits from the three moonless maneuvers and the need for three of them so that the Terra community may discuss this topic at the next meeting.

Kaufman reported that, based upon a request from the EOS Interdisciplinary Science community, the Terra principal investigators will generate, by mid-August, a Web site that shares information on Terra's data products. This Web site should include the details regarding the initial 50-percent data production, data products, validation plans, knowledge of accuracy, file structure, etc. Once established, this site will be announced to the EOS IWG listserv.



An Associate of Arts in Community Colleges for Training in Earth Science (ACTES) Project

— Jay W. Skiles (jskiles@mail.arc.nasa.gov), Principal Investigator, SETI Institute, NASA Ames Research Center, Moffett Field, CA

Introduction

In February of 1996, NASA's Earth Science Enterprise (then Mission To Planet Earth) awarded to the College of San Mateo and NASA Ames Research Center a three-year grant for a project entitled, "ACTES: "An Associate of Arts in Community Colleges for Training in Earth Science – Implementing a Pilot Program for Remote Sensing Analysis and Earth Science Applications." The grant was made in response to an application by the College of San Mateo and NASA's Ames Research Center with the general objective of achieving a community college curriculum, credit for which would be transferable to senior institutions and increase the use of data which had been accumulated by NASA's satellite and aircraft research programs. This program of study would be made available through conventional means and would make use of the Internet for both instruction and dissemination. Furthermore, it was expected that the development of the curriculum would increase interest in Earth science careers among students and increase the awareness of NASA Earth science research and data in the general science curriculum.

The project had a variety of objectives that included:

◊ An AA degree program that would be developed during the project with the primary objective of integrating remotely sensed data into a wide variety of courses.

◊ The material developed would be made available for use in other community colleges. The material would be available in both print and "on-line" form to provide maximum access.

◊ College of San Mateo (CSM) would become a source of curricular materials for other community colleges.

◊ A laboratory for students would be put into place for testing and use of materials developed under the grant.

◊ CSM would recruit students and test materials to be developed during the project.

◊ CSM would disseminate information about the program and the available materials.

Development Methods and Timing

The first stage of development required the establishing of a test laboratory with both Macintosh and PC platforms. With the laboratory in place and teaching facilities obtained, the next step was to obtain permission to develop a new "field" of instruction at the college. The College's Committee on Instruction concurred in the creation of this new field of study, i.e., Earth Systems. The new designation, ESYS, was put in place with an application made to the state Chancellor's office for it to be designated a new program. The Committee on Instruction also gave support for the offering of a special class leading to the development of a permanent introductory class in the new field. With just minimal notice about the project, ten students were enrolled in the first ESYS class at the college. This response occurred with just a brief mention of the class or program in the schedule of classes, since the program had been established too late for regular placement into the schedule and catalog.

This student response compares quite well with the experience of California State University (CSU) Monterey Bay in its startup program in remote sensing. With this experimental class, we were able to test some materials in a classroom setting. The full program of courses for the major was submitted to the Committee on Instruction in April 1997 and two new courses were taught in the academic year 1997-98.

The first phase of the Internet work involved establishing a homepage for the program and introducing the concept of the program through the Internet. A multi-page site (now more than 15 pages) is in place and may be visited at the address: "http://www.smcccd.cc.ca.us/smcccd/csm/actes/actes.html". Outlines of the classes were also mounted on the Internet site in preparation for offering some elements of the major "on-line." Additionally, information about the skill set and proposed matriculation models were also made available on line.

Courses and Major Completed

In the last year (1998-99), the group of five courses that is the heart of the major in Earth Systems was approved by the college Committee on Instruction. The major was also accepted and placed in the catalog to be published for the academic year 1999-2000. Coincident with those approvals was the acceptance of three of the courses for Internet instruction. The State of California requires separate approval for "distance" learning courses, and this approval was obtained from the Committee on Instruction. At this time the articulation process was put into motion to ensure that the new courses would be transferable to nearby California State Universities. Discussions are ongoing with CSU Monterey Bay with its remote-sensing program and with other CSU's with Geographic Information Systems (GIS) and Global Positioning Systems (GPS) programs. Presently, all courses are transferable for regular college credit.

Products

As required, products of the program, curriculum modules, and other supporting materials have been produced. Among them are:

1. A website for the ACTES program with descriptions of the courses, skill sets, suggested matriculation models, and examples of student participation.

2. An automated on-line counseling program which will be made available to all community colleges as part of the dissemination of material. This program, written in java script, can be adapted for use by other colleges.

3. A graphic "concept map" was created as a guideline for development and dissemination.

4. A toolbox containing graphic spreadsheets with illustrations for use in classroom instruction was developed. This toolbox is designed to be used with Microsoft Excel and is specifically organized to assist students in global geometry and a variety of geometric calculations.

5. A resource World Wide Web page with links and annotated bibliography was created.

6. Five course outlines and lessons were developed:
   a. An introductory course in Earth Systems (ESYS 100) complete with 15 instructional modules for use on-line or as assistance to classroom instruction. This material may be easily adapted by any community college for use on-line. It is already in "html" encoded form for web mounting. The course introduces the basic concepts of the study of Earth Systems with emphasis on earth geometry, GIS, GPS, and remote sensing.
   b. A course in visual representation of data complete with 15 instructional modules for use on-line or as assistance to classroom instruction. This material may be easily adapted by any community college for use on-line. It is in "html" encoded form for web mounting. The course introduces the basic concepts of the study of data, data presentation, file types, and modes of visual representation.
   c. An introductory course in remote sensing complete with 18 instructional modules for use on-line or as assistance to classroom instruction. This material also may be easily adapted by any community college for use on-line. It is in "html" encoded form for web mounting. The course introduces the basic concepts of the study of remote sensing, the electro-magnetic spectrum, sensor devices and technology, and file storage and file types.
   d. A course outline with exercises for in-class instruction of GIS and GPS concepts and software. It was decided early on that this was an inappropriate class for on-line or web instruction due to the expense and sophistication of the software involved. Instead, the materials available suggest a methodology and resources necessary for instructional development of the subject.
   e. A course outline for a summary project called the "practicum."

The above materials in number six above are available on line at the ACTES web site for downloading after June 1, 1999. They will also be available soon on CD-ROM.

The Future

Experience with several of the courses has led to the development of strategies for the future. It seems clear at this stage that the coursework involving global positioning and geographic information systems, now taught as a single course, needs to be divided into two separate courses. A proper sequence of these courses will be important as we have noticed a tendency for students to attempt GIS courses without the proper foundation coursework.

A second area for future development is to expand the availability of the introductory Earth Systems course as a "basic" science course for all undergraduates. We consider that the introductory course provides a sound introduction to the science generally, in addition to being the beginning course of the Earth Systems major.

As a full major established in both the college catalog and the semester schedule, Earth Systems is self-sufficient. The major has emerged from its formative development to take its place among the interdisciplinary majors offered by CSM and is available to other community colleges. Furthermore, Earth Systems has a bright future as a basis for transfer science majors and as a basis for employment in the expanding fields of remote sensing, GIS, and GPS.

Points of Contact:

Professor Kenneth D. Kennedy
College of San Mateo
email: (kennedy@smcccd.cc.ca.us),

Professor William B. Rundberg
College of San Mateo
email: rundberg@smcccd.cc.ca.us

J. W. Skiles, Ph.D.
SETI Institute, NASA Ames Research Center
email: jskiles@mail.arc.nasa.gov

MODIS Land Surface Temperature Validation

-—Zhengming Wan (wan@icess.ucsb.edu), University of California, Santa Barbara, CA

In order to validate the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature (LST) algorithm and product, the MODIS LST group at the University of California, Santa Barbara (UCSB), has worked with the thermal-infrared (TIR) instrumentation, methodology, and field measurements since 1993. Six of the field campaigns conducted in 1995-1998 were supported by the flights of the MODIS Airborne Simulator (MAS) (http://asapdata.arc.nasa.gov/ames_index.html gives information on the test sites and flight lines).

Objectives

The primary goal of the field campaigns is to validate the accuracy of the MODIS LST algorithm at an accuracy better than 1 K through validation field campaigns. The secondary goal is to validate the calibration accuracy of seven TIR bands at a radiance accuracy better than 0.5-1.0% through vicarious-calibration field campaigns. These seven bands are used in the day/night MODIS LST algorithm for simultaneous retrieval of land-surface emissivity and temperature. Details of the MODIS LST algorithm are given in its algorithm theoretical basis document (ATBD) (http://eospso.gsfc.nasa.gov/atbd/modistables.html).

Ground-based TIR Instruments

In order to achieve these two objectives, a continuous effort has been made to improve the performance of the TIR instruments used in ground-based measurements and to establish the following necessary functions:

1. accurate spectral measurements of surface emissivity and surface-leaving radiance in the range of 3.5 to 14.5 μm,

2. spectral measurements of surface-leaving radiance at multiple viewing angles in order to compare with the MODIS observation at its exact viewing angle,

3. temporal measurements of the surface-leaving radiance and/or LST in order to exactly match the MODIS observation time,

4. appropriate spatial coverage and sampling of the *in situ* LST measurements for comparisons with the MODIS observation at its 1-km pixel scale,

5. accurate portable blackbodies to calibrate TIR instruments in the field.

A TIR spectrometer was purchased in 1993. This TIR spectrometer is equipped with an InSb / MCT sandwich detector that can provide radiance data at a selectable spectral resolution of 1-to-32 wave-numbers in the spectral range of 3.5-14.5 µm. The 4-wavenumber resolution was selected in our field measurements. At this spectral resolution, the speed of the spectrometer is 8 spectra per second. A series of custom improvements was made to this TIR spectrometer, including the installation of a beam expander, a scanning mirror, three blackbody boxes in front of the spectrometer, and a water cooling system that allows the spectrometer to work in a more stable condition.

The field-of-view (FOV) of this improved TIR spectrometer is approximately 25 cm when it is placed on a platform 3 m above the ground. This TIR spectrometer with the scanning mirror can scan a range of angles to provide temporal and angular spectral surface radiance and atmospheric downwelling irradiance (with a diffuse reflector). The measured downwelling irradiance is used in the atmospheric correction of the ground-based measurement data. The accuracy of the TIR spectrometer is better than 0.15 K in the 8-14-µm range. In this spectral range the signal-to-noise ratio (SNR) of a single spectrum of the TIR spectrometer is greater than 1000. At least 256 sets of spectra are averaged in order to obtain a high SNR in the medium-wavelength range down to 3.5 µm.

A similar TIR spectrometer was combined with a 5-inch infragold integrating sphere for measurements of the spectral directional-hemispherical emissivity. This instrument is primarily used for emissivity measurements of samples such as ice, water, silt, sand, soil, and vegetation leaves.

Laboratory and field measurements of the infrared bidirectional reflectance distribution function (BRDF) and emissivity can also be made with the UCSB Spectral Infrared Bidirectional Reflectance and Emissivity (SIBRE) instrument, which includes a TIR spectrometer, a hemispherical pointing system, a TIR source, and reference plates. The spot size viewed by the SIBRE instrument is approximately 3 cm in diameter so materials with small-scale surface structure can be examined. A beam expander can also be used to give a 12-cm spot for larger structured surfaces.

Heimann thermometers with a FOV of approximately 50 cm at a distance of 2 m are used as broadband radiometers for LST measurements. Their spectral filters of 10-13 µm minimize the effects of uncertainties in spectral emissivities on the atmospheric and emissivity corrections.

These TIR instruments are calibrated with a full-aperture blackbody in a range of temperatures wide enough to cover the surface-temperature conditions in the field. A water-bathed-cone blackbody is also used to check the accuracies of the TIR instruments (including the full-aperture blackbody) routinely in the laboratory. High-precision thermistors (with accuracy better than 0.1 K) used in blackbodies provide the traceability to the NIST standard.

Up to 12 Heimann thermometers are deployed at different locations over an area ranging from 100 m by 100 m to 2 km by 2 km in order to measure the spatial variations at the MAS and MODIS pixel scales. Up to 16 small thermistor datalogger packages are also deployed over the lake or playa test site. The thermistors are placed a few millimeters beneath the lake or playa surface.

A potentially large uncertainty source in scaling the ground-based LST measurements (in FOV of 25-50 cm) up to the MAS and MODIS pixel size is the spatial variation of LST at the 0.2-1-m scale. There are two approaches to measuring the temporal spatial variation of LST at this scale. One is to move a broadband radiometer along a cable at a speed of 1 m / s. Another is to measure the 2-D LST distribution continuously with an IR camera. An AGEMA IR camera provides LST images in 320 lines with 240 pixels per line. In the high-speed mode, the camera can provide 30 image frames per second. The accuracy of the averaged image of LST each second is better than 0.3 K. The measured time series of the 2-D LST image is used to analyze the temporal and spatial variations of LST at the 0.2-1-m scale and at the MAS pixel scale (50 m).

Besides the TIR measurements, a radiosonde is launched before the MAS and / or MODIS overpass to measure the atmospheric temperature and water vapor profile. Based on the measured atmospheric profiles and surface emissivity and temperature, the radiance at the top of the atmosphere (TOA) can be obtained through atmospheric radiative-transfer simulations. The convolution of the derived TOA radiance with MAS / MODIS spectral response functions gives the radiance values in the MAS / MODIS bands corresponding to the measured atmospheric and surface conditions. The MAS / MODIS calibration accuracy can be determined from the comparison between such derived TOA band radiances and the MAS / MODIS band radiances. It is highly desirable to conduct vicarious-calibration field campaigns over large flat homogeneous sites at high elevations under dry clear-sky conditions in order to effectively reduce the uncertainties in the measured atmospheric conditions (due to temporal and spatial variations) and in the atmospheric radiative-transfer simulation.

Synergism of Ground-based and Airborne Measurements

Railroad Valley playa, Nevada, and the area of Mono Lake, California, were selected as primary test sites. The Railroad Valley playa is greater than 15 km in diameter at a surface elevation of 1440 m above sea level. The surface temperature is relatively homogeneous in the central portion during the dry summer season. This site is one of the test sites used to validate LST in the high-temperature range. The first field campaign with MAS flights over this site was conducted jointly with the Advanced Spaceborne Thermal Emission Reflectance Radiometer (ASTER) team and other calibration / validation scientists in August 1995. Mono Lake is greater than 15 km in diameter at a surface elevation of 1945 m above sea level. There are forests, grasslands, and mountains in the Mono Lake area. A flat short-grass field of approximately 2 km by 2 km, to the south of Mono Lake is covered by snow for a period of several days to a few weeks after each major snowfall. The Mono Lake area is one of the test sites used to validate LST in the medium- and low- temperature range.

Six field campaigns were conducted with MAS flights for the validation of MODIS LST algorithms in Railroad Valley, Nevada, and in the areas of Mono Lake and Death Valley, California, in 1995-1998. Only the data collected in the field campaign conducted near Mono Lake in March 1998 could be used for the vicarious calibration of the MAS thermal channels because of the calm clear-sky and dry atmospheric conditions during that campaign (column water vapor less than 0.4 cm). The MAS noise-equivalent temperature difference was estimated with MAS data over three lake-surface sites (unfrozen Mono Lake, and frozen Grant Lake covered by snow and ice in its northern and southern portions, respectively) and one snow-field site. The MAS calibration error was estimated with the MAS data over Mono Lake and *in situ* measurement data over the snow-field site. The uncertainty to be determined in future field campaigns is involved with the spatial variations of LST at the scales from 0.2-1 m up to the MAS pixel size. Another field campaign will be conducted there in February / March 2000 to validate the calibration of MAS and MODIS TIR bands. Once MAS calibration is validated and its long-term stability is established through regular vicarious calibration activities, MAS can be used to validate the calibration accuracy of MODIS TIR channels. At that point, MAS can also be used to validate MODIS LST products in areas with heterogeneous land-cover types and / or in complicated terrains where it is almost impossible to obtain accurate ground-based measurement data at the MODIS pixel scale. The MAS data acquired over the MODIS Land validation core sites will also be used to validate the MODIS LST product.

Field Campaigns Planned for 1999 and 2000

A field campaign over Railroad Valley, NV, and the area of Mono Lake, CA, is scheduled for the period of September 20 to October 15, 1999. During this period, 16 ER-2 flight hours will be used for daytime and nighttime MAS flight missions. The Airborne Visible Infrared Imaging Spectrometer (AVIRIS) has been requested for daytime flight missions. The ER-2 flight schedule will be coordinated with Kurt Thome of the University of Arizona, who has also requested an alternative platform for a MASTER (the MODIS and ASTER Airborne Simulator) flight to coincide with overpasses of ASTER and Landsat 7 during this period of time.

A vicarious calibration field campaign over the area of Mono Lake, CA, is planned for February / March 2000. MAS / AVIRIS flights have been requested for this campaign.

A vicarious field campaign over Uyuni Salt Flats, Bolivia, is being planned for May 2000. There will be no MAS flight for this field campaign.

A field campaign over Railroad Valley, NV, and the area of Mono Lake, CA, is scheduled for June / July 2000 for the MODIS LST validation. MAS / AVIRIS flights have been requested for this campaign.

Collaboration will occur during the ASTER calibration / validation field campaign over Mauna Loa, Hawaii, in April-June 2000. MASTER flights have been requested during the PACRIM-II deployment.

We will join the SAFARI 2000 field campaign to conduct ground-based TIR measurements over Makgadikgadi Salt Pans, Botswana in August 2000.

Close collaboration with the ASTER team and other groups will be maintained for future MODIS LST validation activities, and new opportunities for collaboration in the international efforts to validate LST at the global scale will be pursued.

Summary of NASA EOS SAFARI 2000 Workshop

— Bob Swap (Swapper@virginia.edu), Tim Suttles (tim.suttles@gsfc.nasa.gov), Michael King, Harold Annegarn, Bob Cook, Jim Drummond, Bill Emanuel, John Gille, Peter Hobbs, Chris Justice, Luanne Otter, Stuart Piketh, Steve Platnick, Jeff Privette, Lorraine Remer, Gary Shelton, and Hank Shugart

Overview

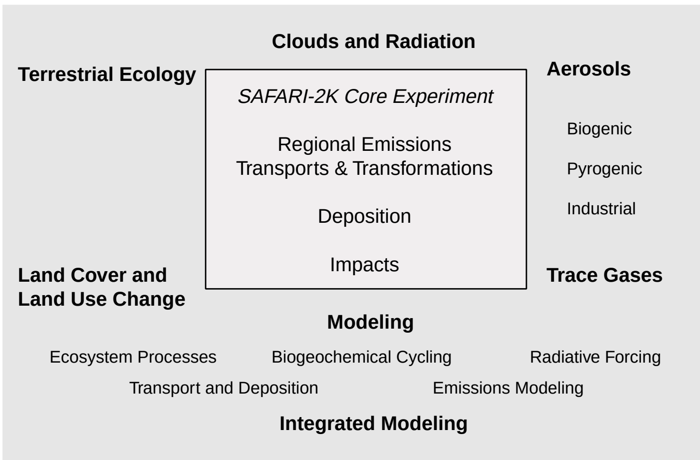


Figure 1: Schematic of SAFARI 2000 Core Experiment

The Southern African Regional Science Initiative, SAFARI 2000, presents an opportunity to study global-change issues on a regional scale in a comprehensive fashion. A level of excitement exists at the prospect of coordinating and leveraging off of existing inter-agency and international research activities in Southern Africa to successfully conduct SAFARI 2000. As part of the progression in the coordination and planning of this regional science initiative, North American and Southern African scientists came together to participate in the NASA EOS SAFARI 2000 workshop held during May 12-14, 1999 at the National Center for Atmospheric Research, in Boulder Colorado.

The Purpose of the Workshop was to review the SAFARI 2000 science plan; identify specific measurement needs and critical gaps in that plan; define and coordinate aircraft platforms and activities; plan and coordinate U.S. contributions to the SAFARI 2000 Implementation Meeting in Gaborone, Botswana, during July 26-30, 1999. Participants in the workshop numbered approximately 60 and were affiliated with various universities and national government agencies.

The Boulder Workshop was conducted over 2 1/2 days. Day 1 was devoted to a review of the evolving plans for the science initiative, the status and progress of funded and planned investigations, and keynote presentations on each of the core elements of the Science Plan. These reviews and presentations set the stage for activities on Day 2, which included Discipline Breakout Groups to address the strategy for core-element activities and potential gaps and Airborne/Surface Measurement Breakout Groups to address the measurement requirements and capabilities. On the final day of the workshop, Implementation Breakout Groups met to define approaches for coordinating and integrating activities of the science steering committee, the airborne operations teams, and the ground-based measurement teams. Reports were presented on the breakout group deliberations, and other discussions were held on coordination between U.S. and in-region research activities; identification of potential collaborative partnerships; data policy and principles; and Memorandum of Understanding, Letter Agreements, and International Protocol needs. The final session concluded with writing assignments to key participants with the objective of converting the workshop results into a U.S. Implementation Plan for SAFARI 2000.

The vision of SAFARI 2000 was presented with the breadth of that vision having followed, in part, from the remaining unanswered questions from SAFARI 92. Those questions focus on: total emissions and magnitude of different emission sources; varying emission estimates and the validation of these estimates; temporal, spatial, chemical, and optical characteristics of the regional atmosphere as related to these emissions; and impacts of these emissions on biogeochemistry, radiative forcing, air quality, and rain production. The concept of a SAFARI 2000 Core Experiment to address many of these unanswered questions was presented (Figure 1). The Core Experiment aims to study aerosol and trace-gas emissions, their transports and transformations, their deposition and their impacts in Southern African as determined by ground-based, and *in situ* and remotely sensed airborne measurement campaigns. The SAFARI 2000 Core Experiment comprises the following core elements: Terrestrial Ecology; Land Cover and Land Use Change; Aerosols; Trace Gases; Clouds and Radiation; and Modeling. Research and EOS validation activities associated with each of the core elements were discussed by the discipline-specific breakout groups.

There was some concern in the breakout groups, given the workshop attendees present at Boulder, about being able to address some of the objectives of the Science Plan to a sufficient level. The breakout groups identified the need to involve a broader community of scientists to discuss ways to achieve some of the objectives of the Science Plan. In particular, the groups identified the need to strengthen the modeling activities (e.g., interdisciplinary modeling, integrated modeling, transport modeling, and ecological modeling). Such issues should be addressed at the upcoming workshop in Gaborone.

A proposed Management Structure for U.S. participation was presented and couched within the existing SAFARI 2000 management structure. This will be developed for review at the Gaborone workshop. Guidelines for participation in SAFARI 2000 were also presented. The need for interactions and negotiations between U.S. and regional scientists to be facilitated by the regional and U.S. SAFARI 2000 secretariats was also stressed. Adherence to established international protocols regarding Memorandums of Understanding, overflight permissions, and mutually agreeable shipping procedures were also discussed. The U.S. international agreements are to be worked by the NASA Office of External Relations and facilitated by the regional SAFARI 2000 secretariat.

Discipline Breakout Groups

Three discipline breakout groups, Land Modeling and Data, Aerosol-Clouds and Radiation, and Trace Gases, were given the charge to evaluate the core-experiment concept and to identify research areas deemed important and not yet sufficiently addressed by SAFARI 2000. These breakout groups discussed existing data sets, funded projects, and proposed projects related to SAFARI 2000. The workshop participants generally reached consensus regarding the broad science goals, the core elements and associated activities, and the idea of a core experiment associated with SAFARI 2000, but it was concluded that questions remain concerning informational and personnel gaps in the initiative. The workshop participants stressed the importance for getting cooperation between measurements and modeling groups. While many of the research activities were viewed as relatively straightforward in terms of the development of a research strategy, others that were perceived as having high science benefit required more discussion and input from researchers with a different complement of expertise than was present at the workshop.

There was consensus on several cross cutting needs:

1) need for an interdisciplinary modeling component examining interactions over several time and space scales;

2) need for modest resources to support the integrating modeling activities associated with SAFARI 2000; and

3) need to further strengthen research components that link surface emission processes of aerosols and trace gases to the atmospheric chemistry and transport in the free troposphere via the planetary boundary layer.

Specific activities requiring additional attention and strengthening include:

1) flux-tower measurements of trace gases (CO_2, O_3 and reactive nitrogen species) and aerosols at both the Mongu and Skukuza micrometeorological tower sites;

2) deposition studies, especially those studies focusing on the dry deposition of aerosols; and

3) atmospheric profiling of the boundary layer and troposphere via balloon studies, acoustic sounders, and additional rawinsondes.

A number of proposals are currently under development to address some of these needs. The most likely funding sources appear to be the NASA Research and Analysis Program and the National Science Foundation. The South African Weather Bureau agreed to construct a proposal to submit to national, regional, and international funding agencies for the procurement of additional rawinsondes to augment daily ascents performed routinely by regional meteorological services.

The Land Modeling and Data Breakout Group stressed the need for in-region field observations during the initial phase of the growing season. Flux-tower and aerosol and trace-gas deposition data, especially for carbon, nitrogen, and sulfur for incorporation into site-specific and regional models were stressed as programmatic needs. Involvement of the vegetation canopy lidar (vcl) instrument team in SAFARI 2000 was highly desirable for the determination of canopy structure and fuel load. The need for climate data records, AVHRR-archived data, and hydrological data in terms of soil moisture and rainfall was also articulated. The involvement of the Tropical Rainfall Measurement Mission (TRMM) and their data products in SAFARI 2000 was seen as highly desirable. The possibility of using the gauged Vaal River catchment and the South African Weather Bureau's (SAWB) overlapping radar network to validate the TRMM products for the southern African sub-continent was identified as a possible project that could produce a significant test of our understanding of the hydro-logical cycle. There is a possible modeling comparison exercise that would make use of a benchmark data set collected along the Kalahari Transect that could provide an important regional-scale test of the current site of dynamic global vegetation models. A clearly defined source of funding to support the necessary integrative and interdisciplinary modeling exercises required by SAFARI 2000 is needed. Data issues focused on the use of the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) on the U.S. side and a regional mirror data site, most likely to be located in Botswana to handle and disperse the data collected in SAFARI 2000. It is planned that the establishment of a mirror data center with meta-data links established by regional participants will be clarified at the Gaborone meeting.

The Aerosol-Clouds and Radiation Breakout Group discussed objectives centered around the physical and chemical characterization of aerosols and their radiative effects, linking aerosol characteristics to fire sources, and cloud-aerosol interaction in maritime clouds. The implementation strategy required to address those objectives was viewed as straightforward. In terms of objectives focusing on the evolution of physical, chemical, and optical properties of aerosols, biogenic aerosol, and cloud-aerosol interaction in continental clouds, the implementation strategy is not yet clear, but discussion has commenced. Similarly, linking aerosol and cloud studies to ecological modeling, requires further attention. This group also requested additional ancillary data sources in the form of rawinsondes and drop-sondes as well as access to data sets from the NASA Data Assimilation Office (DAO) and the SAWB. Input from transport models is also required for mission planning and post –intensive data analyses. A suggestion was made that those researchers who have the expertise to tie aerosol transports and deposition to ecological modeling provide the leadership necessary to address this goal of SAFARI 2000.

The Trace Gases Breakout Group was able to make significant advancement in meeting the charges given to them during the workshop. Through their extensive discussions and deliberations, they were able to produce a number of recommendations to the SAFARI 2000 steering committee. Chief among them were the following:

1) strong need for compilation and maximum utilization of existing databases that include a variety of forms of printed material, CD publications, and electronically stored data;

2) the formation of a measurement-modeling liaison working group to aid in the designing of *in situ* flight plans and sampling strategies;

3) need to measure dew composition and precipitation concentration to address issue of dry and wet aerosol sinks;

4) the study of frequency and intensity of lightning as a measurement of opportunity to aid in determining the production of NO_x;

5) need for inter-comparison of airborne and spaceborne systems;

6) enhancement of existing meteorological infrastructure within the region—augmentation of upper-air sondes and trajectory analysis support.

7) the need to better constrain estimates of the contributions of biogenic emissions to the budgets of aerosol and trace gases in the region.

Additional points included the need to understand biogenic hydrocarbon production, especially during the critical time of vegetation leaf out. The Trace Gases working group also identified a number of questions and implementation strategies to address those questions in their group report.

The discipline groups, especially the Land-Modeling and Data Group, expressed the need for involvement of regional scientists and their scientific input especially in the areas of identification of surface sites and processes of scientific interest to the SAFARI 2000 effort. There was also a feeling that those investigators new to the region should familiarize themselves with the science and data products of existing research efforts. Along these lines, it was suggested that those researchers in need of such information should contact the SAFARI 2000 webpage (http://safari.gecp.virginia.edu) and /or the regional coordination secretariat. The general feeling during the Boulder workshop was that the Gaborone meeting is an important vehicle to further interactions, discussions, and negotiations involved with SAFARI 2000 collaborative research activities, especially in the area of strengthening the land components with the objective of being able to collaborate with local experts and further develop logistical arrangements.

Aircraft Breakout Groups

SAFARI 2000 intends to use the atmospheric gyre as a physically integrating mechanism. This is beneficial in that southern African climatologies exist that allow for the establishment of a relationship between information in the long-term satellite record and the local observation sites. Airborne measurements are essential to achieve the goals of the experiment. Aircraft platform availability and participation were discussed in detail. The platforms committed to involvement in SAFARI 2000 include the NASA ER-2; the University of Washington Convair 580; and the South African Weather Bureau Aerocommander 690s. The opportunity to have the Proteus, a newly-developed, high-altitude, high-endurance remote sensing platform received much interest from the workshop participants. Its availability to SAFARI 2000 is subject to the Proteus team's success in securing additional resources.

Consensus was achieved among key U.S. and regional scientists to consolidate the scientific decision-making processes related to airborne operations during the August-September 2000 campaign at Pietersburg, RSA. Coordination, communications, and planning associated with aircraft missions will be conducted through the SAFARI 2000 aircraft mission-control center at Pietersburg. For aircraft planning at the control center, it is essential to have daily meteorological forecasting and access to Meteosat Satellite Imagery. To initially facilitate this project coordination and planning, the August – September 2000 flying campaign will begin with all of the aircraft involved with SAFARI 2000 based at Pietersburg for at least one week.

The In-Situ Aircraft Group focused on design of the SAFARI 2000 dry-season airborne campaigns. The experiments requiring *in situ* observations include:

Terra Underflights—radiometric calibration and data product validation for aerosol retrievals, smoke/cloud masking, and fire detection and characterization;

Namibian stratus studies—cloud retrievals and indirect effects;

Biomass burning studies—"box studies," fire emission factors, chemical, physical and optical evolution of emissions downwind of fires;

Industrial source studies—flights of opportunity looking at possible direct and indirect forcing effects.

The types of proposed flight tracks to meet the above needs are as follows:

1) Cross-section wall flight sampling of the gyre with multiple aircraft

2) Probe investigation flights of the gyre, both Lagrangian and Eulerian, by single aircraft

3) Biomass burning flights—fire detection and smoke/emission sampling flights

4) Coordinated flights involving remote sensing observations platforms (satellite, ER-2, Proteus) and *in situ* observational platforms (Convair 580, Aerocommander 690A's)

5) Marine stratus

6) Overwater flights

The various logistical needs for these different flight missions were discussed. There was general agreement concerning the utility of convening an airborne planning simulation exercise to be held in the region early next year in preparation for the August-September, 2000 intensive flying campaign.

Recommendations

Summary Recommendations were arrived at from the various discussions during the meeting:

1) Need for the additional involvement and funding of interdisciplinary, integrative modeling activities linking land and atmosphere

2) Need to strengthen links between ground observations and airborne observations
   - Augmentation of regional rawinsonde network to profile-the free troposphere
   - Acoustic sounder and pilot-balloon studies to describe the planetary boundary layer
   - Instrumentation of existing towers for flux studies of heat, moisture, momentum, and aerosols/trace gases to describe interactions between vegetation and boundary layer
   - Aerosol and trace-gas deposition studies to detail atmospheric contribution to vegetated systems

3) Involvement of a TRMM validation activity within SAFARI 2000 was deemed highly desirable

4) Coordination of all U.S.-sponsored activities in SAFARI 2000 through the regional secretariat office and compliance with protocols and international agreements for in-country research

5) Need for funding to support regional scientists, outside of South Africa, to participate in SAFARI 2000

Report of EOS Volcanology IDS Team Meeting

— Pete Mouginis-Mark (pmm@pgd.hawaii.edu) Team Leader
— Joy Crisp (joy@glassy.jpl.nasa.gov) Deputy Team leader

The latest meeting of the EOS Volcanology Team was held at the University of Hawaii at Manoa May 18th – 23rd, 1999. Numerous Team Members were in attendance, including members from CSIRO (Australia), the Open University (England), JPL, NASA Goddard, and universities in California, Michigan, and North Dakota. Many people from the University of Hawaii, including several graduate students, were also able to participate in the discussions.

The main goal of the meeting was to prepare the Team for the impending launch of the Terra spacecraft. A critical part of this preparation was a review of the volcano data sets that will be collected by each instrument, since many of the high-resolution observations will not be made continuously by Terra, Landsat 7, or the foreign-partner radars. There was also the need to demonstrate our web-based software and the computer code that has been developed by the team for the analysis of thermal monitoring and volcanic gas studies. Other goals were to develop a strategy for how the Team will interact with the media, what our public outreach efforts will be in the first six months of the mission, and what other data sets are becoming available to the volcanology community.

Some of the highlights of the meeting included:

1) Anne Kahle (JPL) reviewed the current plans for volcano data acquisitions as an ASTER Science Team Acquisition Request (STAR). Luke Flynn (Univ. Hawaii) covered the comparable acquisition plans for Landsat 7, since he is also a Landsat 7 Science Team member. Particularly important will be the thermal studies of active lava flows and domes from ASTER and ETM+ on Landsat 7, as well as the digital-elevation models that will be derived from stereo ASTER scenes. More than 30 different volcanoes around the world will be monitored on a regular basis by the Team using these two sensors. These volcanoes include Erebus (Antarctica), Lascar (Chile); Galeras (Columbia); Arenal and Poas (Costa Rica); Fernandina (Galapagos Islands); Erta Ale (Ethiopia); Piton de la Fournaise (Reunion Island); Fuego, Pacaya, and Santa Maria (Guatemala); Hekla and Katla (Iceland); Agung and Merapi (Indonesia); Stromboli, Vulcano, and Mt. Etna (Italy); Sakura-jima and Unzen (Japan); Popocatepetl (Mexico); Ruapehu and White Island (New Zealand); Cerro Negro, Masaya, and Telica (Nicaragua); Manam and Rabaul (New Guinea); Mayon (Philippines); Soufriere Hills (Montserrat); Kilauea (Hawaii); and Nyamuragira and Nyriagongo (Zaire). It is clear that as data for these sites become available, the volcanology community at large will see a dramatic increase in the number and quality of observations that can be made in the thermal infrared.

2) Howard Zebker (Stanford) and Harold Garbeil (Univ. Hawaii) have been working extensively with radar interferometry studies of volcanoes. The most notable recent success has been the analysis of the 1995 eruption of Fernandina volcano in the Galapagos Islands, where the dimensions of an intrusive dike have been quantified. There is a growing database of pre- and post-eruption radar scenes that will provide exciting new perspectives on intrusive processes as well as the role of topography on the emplacement of new lava flows. Additional radar studies, this time of the 1998 eruption of Cerro Azul (also in the Galapagos Islands), are expected to enable the flow path of the new lava to be compared with predictions based on digital-elevation data collected from the TOPSAR instrument.

3) Over the last year, considerable effort has been expended by Arlin Krueger (NASA Goddard), Bill Rose and Gregg Bluth (Michigan Tech. Univ.), Dave Schneider (Alaska Volcano Observatory), and Fred Prata (CSIRO) on the analysis of volcanic plumes, and how the entrained gas phase sometimes disassociates from the ash when the plume reaches high altitude. Understanding this process is vitally important for quantitative models of eruption plumes as aircraft hazards, and also as impacts on short-term climate change; for instance, the sulfate aerosols can significantly affect the Earth's radiation budget. Various Team-developed retrieval algorithms were discussed, as well as ideas for new sensors / missions to augment the EOS data sets. Lori Glaze (Proxemy Research) and Lionel Wilson (Lancaster Univ., England) have devel-

oped software for the analysis of plume geometry with MODIS data, which has been used with AVHRR data to study plumes from the 1989 eruption of Redoubt volcano, Alaska. This algorithm will also be valuable for the analysis of plume heights, particularly if real-time MODIS data become available, due to the extreme hazards posed by eruptions to aircraft encountering the plume. Arlin Krueger reviewed the status of the retrieval algorithms for mapping abundances of ash and sulfur dioxide using TOMS data.

4) Innovative gas studies using FTIR measurements were presented by Peter Francis (Open Univ.) for Mt. Etna and Masaya. These field measurements used hot targets placed several kilometers away, and demonstrated the use of solar and lunar illumination sources. The potential for using similar ground-based measurements to validate TES data for plumes was discussed. Aircraft thermal-infrared data (TIMS and AES) for sulfur-dioxide mapping at Kilauea volcano were described by Vince Realmuto (JPL). Vince has developed a new version of his sulfur-dioxide retrieval algorithm that can be run on a PC, thereby enabling many more investigators to use this technique once ASTER data become available. Monitoring the temporal variation of gas flux at volcanoes around the world is expected to contribute to our understanding of the global budgets of tropospheric and stratospheric sulfur dioxide.

5) Excellent computer demonstrations were given by Luke Flynn and Eric Pilger (Univ. Hawaii) on the real-time detection and analysis of volcano thermal anomalies by GOES, the derivation of maps of sulfur-dioxide abundance in plumes (Vince Realmuto), and a new volcano database created by Chris Okubo (Univ. Hawaii). The GOES data were initially used to model our planned MODIS thermal alerts, but now that the full potential of these GOES data has been realized, a number of alternative ways of supporting this as a separate effort are being pursued.

These web-based activities are expected to become even more important when Terra is flying, because they will often be the initial method by which the volcanology community will learn about the new data sets and, in the case of MODIS thermal alerts, as near-real-time observations. The MODIS alerts will be presented via a similar web-based interface and will cover the Earth once every 1.5 days. Global, regional, and special-interest volcano maps will provide easy access to near-real-time MODIS data of hot spots. In addition to building a comprehensive database for future science investigations of volcano thermal activity, they will also help the Team to direct high-resolution instruments such as ASTER, and Landsat 7, and EO-1 instruments to designated targets.

6) A series of brief discussions of the radar remote-sensing and topographic studies being conducted by investigators from Hawaii was provided. These presentations included a new method for the determination of lava effusion rates from time-series analysis of digital-elevation models (Scott Rowland, Univ. Hawaii), temporal studies of lahar formation at Mt. Pinatubo (Ronnie Torres and Steve Self, Univ. Hawaii), and the analysis of catastrophic landslide emplacement on Socompa volcano, Chile (Mary MacKay, Univ. Hawaii). All of these studies hold great promise for the Team's ability to work with new digital-elevation data to be produced from ASTER and the up-coming SRTM, VCL, and ICESat missions. Topographic difference maps, that can estimate volumetric rates of change, were seen to hold particular promise for studying active volcanoes.

Outreach efforts were also discussed. A lively debate ensued during this part of the meeting, as many of the volcanic eruptions seen by Terra and other spacecraft will have immediate social and economic impacts. Where real-time data become available (for example, via MODIS Direct Broadcast), great care will have to be taken to follow the appropriate agency procedures when contacting the responsible officials (e.g., IAVCEI, 1999). This care must be included whenever press releases are written by the Team and the EOS Project Science Office, as well as our other interactions with the media (always contacting responsible officials before the press). The IDS Team has already established strong ties with foreign volcano observatories through the real-time collection and analysis of GOES thermal data. These data are displayed on a public Web site in the form of maps of locations of thermal alerts in near real-time, which can be viewed and interpreted by anyone. In no case are remote-sensing interpretations by the EOS Volcanology Team released directly to the general public; rather there is always a local responsible volcanologist who is informed of the observations and then takes the appropriate steps. It was recommended that the same attention to detail concerning the potential impact of the Terra data on local and foreign communities dealing with volcanic activity be followed. Warnings or forecasts should not be made based on remote-sensing data alone. It should be left up to the on-site volcanologist team leader or spokesperson to incorporate the remote-sensing information into their decisions and statements.

We also heard about preliminary plans to present a workshop at the upcoming International Association of Volcanology and Chemistry of the Earth's Interior (AVCEI) meeting next year. In addition, members of the Team are in the final phases of editing a Monograph for the

American Geophysical Union on the "Remote Sensing of Active Volcanoes" that we hope will introduce many traditional geologists to satellite remote-sensing methods. Ideas for a second review article in an international journal for the Team's approach to volcano remote sensing were also discussed.

Finally, the meeting ended with an informative trip to Kilauea volcano on the Big Island. The focus of this trip was to explore some of the ASTER calibration/validation sites that may be used during the Terra mission, as well as to identify some possible study sites for joint Univ. Hawaii/CSIRO aerosol studies. We also visited some active lava flows and ocean entry points. It rained much of the time!

More details of the Volcanology Team's efforts are available at: http://www.geo.mtu.edu/eos/

The real-time use of GOES data for volcano monitoring can be seen at: http://volcano1.pgd.hawaii.edu/

Reference

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NASA's Earth Science Enterprise Participates in the Odyssey of the Mind World Finals

— Steve Graham (steven.m.graham.2@gsfc.nasa.gov), EOS Project Science Office, Raytheon ITSS

What are kids doing after school? If they're like the more than 250,000 kids worldwide who annually participate in the Odyssey of the Mind (OM), they are putting after school hours to good use towards a positive end—a trip to the annual Odyssey of the Mind World Finals. The University of Tennessee-Knoxville hosted more than 5500 finalists, from kindergarten through college age, May 26-29, 1999 at the largest creative problem-solving competition for children and young adults.

Odyssey of the Mind long-term problems are creative challenges that encourage kids to think divergently; in other words, to stretch their imaginations and develop skills that will serve them well in the real world, where there is not always one right answer for every question. This year, NASA's Earth Science Enterprise, through a grant, proudly sponsored one of the five long-term problems, the "EnvirOMental Challenge."

By sponsoring an OM problem, it was NASA's goal to inspire students to gain a better understanding of the global environment by exploring the interaction between the Earth's systems of air, land, water, and life. OMers participating in the EnvirOMental Challenge problem this year were given the task of finding an environment that an Earth species can live in. One of OM's overall goals is to help students learn real-world skills such as "working with others as a team, evaluating ideas, making decisions, and creating solutions."

"Having NASA as a sponsor really gave us a jumping off point. They definitely influenced the nature of the problem because they are one of the only organizations that studies the entire Earth." said

Lynn Macey, Co-International Problem Captain.

Teams of 5 to 7 students compete in one of four age groups, with divisions being determined by the age of the oldest team member. All teams receive the same problems. However, the complexity of their solutions varies according to their age group and all are judged on creativity, design, and style.

Teams choosing to solve the EnvirOMental Challenge presented a performance about an Earth species that required atmosphere, water, and land for survival, and whose home habitat suffered disruption and was deemed uninhabitable. Four potential new habitats were available but whether the Earth species could live in any of them was unknown. During the performance, the team collected samples representing atmosphere, water, and land from the habitats and analyzed them with a discriminating device to determine whether each habitat was suitable for the species. The result of the evaluations had to be communicated by a non-verbal method and displayed at each habitat. The teams' performances were limited to 8 minutes for their performance, and they could spend no more than $100 on materials.

The EnvirOMental Challenge was designed to encourage students to think critically and cooperatively about a complex problem in the same way that Earth scientists, weather forecasters, farmers, fishermen, politicians, and planners must confront the dual challenge of understanding how natural processes affect humanity, and how we affect those same natural processes. NASA is proud to include OM in a long list of partners who are working together to improve our knowledge of the Earth and to use that knowledge for the benefit of all humanity.

In addition to sponsoring the EnvirOMental Challenge, members of GSFC's EOS Project Science Office hosted an Earth Science Enterprise exhibit at the 1999 World Finals. Posters, Lithographs, Fact Sheets and other outreach and educational materials were distributed to approximately 8000 students, coaches, and parents during the four-day finals tournament. During the exhibition, many of the students, coaches, and parents expressed sincere thanks for NASA's support and also commented that the EnvirOMental Challenge was the most challenging and rewarding of this year's five problems.

Now in its 20th year, Odyssey of the Mind involves children and adult volunteers in 50 states and 42 countries. Each September, kids anxiously await the unveiling of the year's challenges, and then form teams to develop a unique solution. Working with an adult coach who can steer but not advise them, teams typically develop, test, abandon, and redevelop a variety of solutions before perfecting the one they'll take to local competition. If they prevail at local tournaments, they'll move on to regionals and then World Finals. The OM Association, Inc., provides curriculum and support materials for teachers who want to incorporate the competition's spirit of creative problem solving into daily classroom activities.

See table below for the results of the 1999 World Finals EnvirOMental Challenge.

Division I	
1. Del Prado Elementary School	Boca Raton, FL
2. Valwood School	Valdosta, GA
3. North School	Des Plaines, IL
4. Glenlyon-Norfolk School	Victoria, BC
5. Trombly Elementary School	Grosse Pointe Par, MI
6. Wright City Elementary School Team B	Wright City, MO
Division II	
1. Londonderry Middle School Team Orange	Londonderry, NH
2. Walker Middle School	Salem, OR
3. Powell Middle School	Littleton, CO
4. Blalack Middle School	Carrollton, TX
5. Lindbergh Middle School Team A	Peoria, IL
6. Waterford O E O / Gold Program	Waterford, MI
Division III	
1. Georgetown Ridge Farm High School Team B	Georgetown, IL
2. Greenville High School	Greenville, TX
3. Fergus Falls Middle School	Fergus Falls, MN
4. Monson Jr / Sr High School Team A	Monson, MA
Ft. Meyers High School Team A	Fort Myers, FL
5. Lavista Jr High School Team B	Lavista, NE
Heritage High School	Littleton, CO
6. Pinkerton Academy Team A	Derry, NH
Division IV	
1. University of Texas / Dallas	Richardson, TX
2. Sierra Nevada College	Incline Village, NV

Special awards were also given to those teams displaying exceptional creativity. This year's *Ranatra Fusca Award* was given to a Division II team for their development of an extremely unusual method of sample discrimination for the EnvirOMental Challenge. Congratulations to the team from Central Middle School in White Bear Lake, Minnesota. Their unique and "out of the box" solution involved the "parrot" team members physically becoming an integral part of the four habitats. They made an intuitive leap to discriminate elements qualities using an assembly-line process, making each parrot an element specialist.

The *Outstanding OMer Award* recognizes those OMers coaches, individuals, team members, parents, officials, and others that serve as OM examples or role models by their actions or words. It is also bestowed on team members who exhibit exceptional skill, as opposed to creativity. As with the Ranatra Fusca Award given for creativity, recipients of the Outstanding OMer award receive a special medal. Two of this year's recipients were participants in the EnvirOMental Challenge. Congratulations to Bruna Andrade of Colegio Int. DeCarabol in Valencia, Venezuela. After the contamination of all her team members Bruna realized she could not get to the remaining 2 habitats in any safe manner and employed humor to include the audience in her thought processes. She ad-libbed, while maintaining her poise, stayed in her character, and proceeded with the role playing of a Fortune Teller trying to read the suitability of the 2 remaining habitats through the use of her crystal ball. Congratulations to Meg Waddell of Hightower Trail Middle School in Marietta, Georgia. Meg composed an original "Oreawhale" song in the Italian Bel canto style. She also invented

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EOS Scientists in the News
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EOS Scientists in the News

— Emilie Lorditch (elorditc@pop900.gsfc.nasa.gov), EOS Project Science Office, Goddard Space Flight Center, Greenbelt, MD 20771

"NASA Satellites May 'Revolutionize' Earth Sciences," *The Chronicle of Higher Education* (July 9) by Kim A. McDonald. Over the next four years NASA's Earth Observing System will launch 26 satellites to measure Earth's climatic system in greater detail and more comprehensively than ever before. Durng the workshop, *Future Directions in Global Change Research: A Workshop for Journalists*, that was held on June 24, James Hansen (NASA GISS), Ghassem Asrar (NASA HQ), Michael King (NASA GSFC), Yoram Kaufman (NASA GSFC), Mark Abbott (Oregon State Univ.), Steven C. Wofsy (Harvard Univ.), and David Randall (Colorado State Univ.) discussed the scientific plans and satellite missions that will examine the Earth's climate.

"Lack of Icebergs Another Sign of Global Warming," *Science* (July 2) by Bernice Wuethrich. For the first time in 85 years, the International Ice Patrol did not issue a single bulletin about icebergs. John M. Wallace (Univ. of Wash.) says that since the 1980s, winter temperatures have risen at least 0.5 degreess Celsius.

"Jet Contrails Likely to Add to Earth's Warming," Reuters (June 23). Jet contrails will contribute significantly to global warming within the next 50 years. Patrick Minnis (NASA LaRC) has been studying contrails over parts of the United States and Europe. Minnis' team calculated that by 2050 the average contrail cover over the United States will increase 2.6 times current levels.

"Craft to Track Climate-Affecting Link of Sea and Wind," *New York Times* (June 15) by Warren E. Leary. The continuous interplay between wind and ocean eventually affects Earth through its influence on weather and climate. Ghassem Asrar (NASA HQ) says that QuikScat will study this crucial interaction that up till now has gone unmonitored.

"Enormous Haze Found Over Indian Ocean," *New York Times* (June 10) by William K. Stevens. Scientists have discovered that a haze of air pollution about the size of the United States covers the Indian Ocean in the winter. Veerabhadran Ramanathan (Scripps) says that it is too early to say whether this haze has a cooling or warming effect on climate.

"Scientists Predict NYC Storm Surges," *Associated Press* (June 4) by Jeff Donn. New York City could suffer huge storm surges as often as every several years if the sea rises as expected during the coming century. Cynthia Rosenzweig (NASA GISS) says that the surges could break through barrier islands and flood low-lying parts of lower Manhattan, Brooklyn, Queens, and other places in the metropolitan area.

"Twin Cyclone Pattern Linked to Flooding of Yangtze River," *Associated Press* (June 3) by Jeff Donn. Scientists have found a link between weather patterns that can potentially be used to help predict devastating floods in China's Yantgze River. William Lau (NASA GSFC) observed a pair of early May cyclones over the Indian Ocean that seemed to delay, by a week, the onset later that month of the storm pattern known as the South China Sea monsoon.

"Snowpack Here Could Shrink in Future Years," *Associated Press* (June 2). The Pacific Northwest could be facing more raining and flooding, but also a shortage of usable water in the coming decades. Dennis Lettenmaier (Univ. of Washington) says that the region's mountain snow-packs could decline drastically within the next 25 years because of global warming.

"NASA Says Polar Winds Might Cause Winter Storms," *Reuters* (June 2). Rising winter temperatures across the Northern Hemisphere are expected to generate more winter storms. In a study published in Nature, Drew Shindell (NASA GISS) reports that warmer winters bring wet weather to Europe and western North America with western Europe being the worst hit by storms off the Atlantic Ocean.

"Politics Keep Earth-Viewing Satellite Earthbound," *New York Times* (June 1) by Warren E. Leary. Triana, the Earth-viewing satellite initiated by Vice President Al Gore, has been criticized because of its origin and mission. However, Steven Wofsy (Harvard Univ.) says that although he was initially skeptical about Triana, he is impressed at how carefully planned the experiments are. Triana's main objective is to continuously monitor the Earth's entire sunlit face.

"Finding Ocean Temps in the Ice," *Christian Science Monitor* (May 21) by Peter N. Spotts. Drew Shindell (NASA GISS) says that climate models suggest that global warming could strengthen the Arctic Oscillation near the North Pole and lead to changes in snowfall and rainfall patterns in Eurasia, a shift in North Atlantic fishing grounds, and even the disappearance of Arctic ice in the summer.

"New Focus of Climate Fears: Altered Air Currents," *New York Times* (May 18) by William K. Stevens. A new study suggests that events like El Niño will occur more frequently because of the impact of global warming on current air patterns. Kevin Trenberth (NCAR) says that the frequency of El Niño events is dependent on how long tropical storms take to recharge their heat source.

"Ozone Optimism," *Christian Science Monitor* (May 3) by Peter Spotts. Global agreements to slow the production of ozone-destroying chemicals are working, says Michael Prather (Univ. of California at Irvine) in a study published in *Nature*. But more needs to be done to reduce emissions of compounds like CFC-12 that attack ozone.

"NASA Gives Kids Window on North Pole," *CNN Interactive* (April 27). A new NASA World Wide Web site gives people possibly their only chance to see the North Pole. Scientists from NASA's Goddard Space Flight Center are testing ozone levels, measuring ice thickness, testing water and soil pH, as well as participating in online chat sessions. Students can e-mail the scientists and also watch them live as they conduct their research.

"La Niña is on Its Way Out," *CNN Interactive* (April 26). La Niña is beginning to fade, reveals an image from the U.S.-French TOPEX/Poseidon satellite. The image shows that conditions in the equatorial Pacific Ocean are slowly returning to normal, but it also suggests that current ocean temperatures are still abnormal.

"Disappearing Ice Down South," *Science News* (April 24) by Richard Monastersky. The glacial shelves surrounding the Antarctic Peninsula are melting because of increased temperatures in the region. Ted Scambos (Univ. of Colorado) says this melting has no impact on global sea-level rise, because the ice shelves are already floating in water.

"El Niño May Slow Global Warming," *CNN Interactive* (April 15). The ocean released 30-80 percent less carbon dioxide during the El Niño years of 1991-1994, reports a study published in Nature. According to Scott Doney (NCAR), the study, which used data from 80 weather stations, captured an important time period in showing what is happening to carbon dioxide during an El Niño event.

"NASA Launches New Earth-Imaging Satellite," *Associated Press* (April 15). NASA's Landsat 7 satellite will monitor global conditions ranging from land surface change and snow packs to floods and fires, reports Darrel Williams (NASA GSFC). Williams says that Landsat 7 was designed to monitor the same area every 16 days.

"Two Scientists Find a Mission at Hampton U.," *The Chronicle of Higher Education* (April 9) by Jason Hughes. James M. Russell III (Hampton Univ.) and M. Patrick McCormick (Hampton Univ.) formerly of NASA's Langley Research Center, took positions at Hampton

University to increase interest in physics among black students. The program is gaining momentum in its second semester with 12 undergraduate and three graduate students.

EOS researchers please send notices of recent media coverage in which you have been involved to: Emilie Lorditch, EOS Project Science Office, Code 900 Goddard Space Flight Center, Greenbelt, MD 20771. Tel. (301) 441-4031; fax: (301) 441-2432; e-mail: elorditc@pop900.gsfc.nasa.gov

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NASA's Earth Science Enterprise Participates in the Odyssey of the Mind World Finals

an "orea" language using no English Words. The hauntingly beautiful melody conveyed perfectly the emotion of the heart-broken whale. She applied her outstanding musical talent in an unusual and effective manner.

OM estimates that approximately 2,140,000 students, parents, teachers, administrators, and spectators were exposed to the EnvirOMental Challenge over the course of the 1998/99 school year. Talk about a return on your investment!

Earth Science Education Program Update

— Nahid Khazenie (nkhazeni@hq.nasa.gov), Education Program Manager, Office of Earth Science, NASA Headquarters

Your One-Stop for NASA Education

NASA's Earth Science Education Program is working to better leverage Enterprise endeavors through the NASA Education Home Page. The goal is to make the NASA Education Homepage a one-stop "shopping" site for educators where everything related to NASA education is posted and linked from this site. You can visit the site at: http://education.nasa.gov.

First NASA Earth Science Education Forum will be held in Austin

The NASA Earth Science Education Forum will be held November 14-17, 1999 in Austin, Texas, at the Omni Downtown Hotel. This will be the first time that NASA brings together members from all parts of its Earth science education program, from elementary through university level projects, including Earth science and education representatives from NASA Headquarters, all NASA Field Centers, universities, non-profit organizations, and private companies.

The conference is intended to meet the following objectives:

- Communicate NASA's Earth science education strategy and vision for the future.
- Share knowledge and experience gained as a result of NASA ESE education activities.
- Encourage leveraging and cooperation among projects.
- Share resources and unique approaches to enhance current programs.

As a result of the conference, NASA hopes to:

- Identify possible gaps in its overall Earth science education program.
- Identify the extent of equity, diversity, and access in all activities.
- Identify overall program improvements.

The Institute for Global Environmental Strategies (IGES) is organizing this event and has developed a conference WWW site, where you can register on-line at http://www.strategies.org/conference.html. For more information about the conference or to register, please visit the WWW site or contact Theresa Schwerin, email: theresa_schwerin@strategies.org.

Terra Launch Conference for Educators

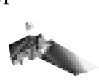
A conference for educators will be conducted in conjunction with the Atlas Centaur launch of the Terra Earth Science satellite at Vandenberg Air Force Base, California.

Terra ushers in a series of Earth-orbiting satellites that will enable researchers to understand how the atmosphere, land, and ocean interact with each other on a global scale. Instruments provided by the United States, Canada, and Japan will simultaneously study clouds, water vapor, aerosol particles, trace gases and terrestrial and oceanic properties. In addition they will measure the changes in land and ocean surface and interaction with the atmosphere through exchanges of energy, carbon, and water. Curriculum areas most affected by Earth Science research include: water, coastal, agriculture, forestry and range resources; geology, environmental monitoring, and land use. Terra Project scientists, engineers, and the educational community will address the science, technology, and classroom applications associated with the mission.

NASA and the California Central Coast NASA Educator Resource Center, in cooperation with the U.S. Air Force, will host the conference. For further information, please call (650) 604-5543 or go to the Terra web site at http://terra.nasa.gov.

El Niño Pudding

'El Niño pudding', a great activity and delicious treat, and its link to the global climate event are now staged on the highly acclaimed NASA children's site; SpacePlace at http://spaceplace.jpl.nasa.gov/topex_make1.htm.



EOS Science Calendar

September 22
TES Science Team meeting, Harvard University, Cambridge, MA. For local arrangements Contact: Daniel Jacob, tel. (617) 495-1794, email: djj@io.harvard.edu; for agenda information contact Reinhard Beer, tel. (818)354-4748; email: Reinhard.Beer@jpl.nasa.gov.

September 28-30
NSIDC DAAC User Working Group Meeting (PoDAG) Boulder, Colorado

Global Change Calendar

August 2-6
18th Congress of the International Commission for Optics, San Francisco, CA. Contact: ICO XVIII Conference Manager, SPIE, 1000-20th Street, P.O. Box 10, Bellingham, WA 98225, tel. (1) 360 676 3290; Fax: (1) 360 647 1445; email: ico18@spie.org

September 8-10
Non-CO_2 Greenhouse Gases (NCGG-12) Scientific understanding, control and implementation, Noordwijkerhout, The Netherlands. Call for Papers. Contact Joop van Ham, e-mail j.vanham@plant.nl, Fax: +31-15-261 3186.

September 13-15
IEEE International Workshop on Multimedia Signal Processing, Copenhagen. Contact Jenq-Neng Hwang, e-mail: hwang@ee.washington.edu, URL: http://eivind.imm.dtu.dk/mmsp99/

September 13-17
Sixth Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC), Bologna, Italy. Call for Papers. URL: http://www.fisbat.bo.cnr.it/IGAC99/.

September 15-17
Second International Workshop on Multi-angular Measurements and Models, ISPRA, Italy. Contact Michel Verstraete, e-mail: michel.verstraete@jrc.it, URL: http://www.enamors.org.

September 20-24
Conference on Sensors, Systems and Next Generation Satellites V, University of Florence, Italy. Call for Papers. Contact Steve Neeck, email: steve.neeck@gsfc.nasa.gov.

November 2-5
The CEOS Global Observation of Forest Cover (GOFC) Meeting on Fire Mapping and Monitoring, the Joint Research Center, Ispra, Italy. For further information contact Frank Ahern, email: Frank.Ahern@CCRS.NRCan.gc.ca

2000

March 27-31
28th International Symposium on Remote Sensing of Environment, Cape Town, South Africa. Call for Papers. For abstracts submission: abstracts@mikom.csir.co.za or http:www.isrse.co.za, Fax: +27 21 883 8177; Tel: +27 21 886 4496 (ask for Deidré Cloete); postal: The 28th ISRSE technical committee, PO Box 452, Stellenbosch, 7599, South Africa.

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

July 24-28
IEEE 2000 International Geoscience and Remote Sensing Symposium, 20th Anniversary, Hilton Hawaiian Village, Honolulu, Hawaii. Call for Papers. For up-to-date data regarding submissions, access the conference website at www.igarss.org.

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The Earth Observer Staff:

Executive Editor: Charlotte Griner (charlotte.griner@gsfc.nasa.gov)
Jim Closs (jim.closs@gsfc.nasa.gov)
Technical Editors: Bill Bandeen (bill.bandeen@gsfc.nasa.gov)
Renny Greenstone (renny.greenstone@gsfc.nasa.gov)
Design and Production: Winnie Humberson (winnie.humberson@gsfc.nasa.gov)
Distribution: Hannelore Parrish (hannelore.parrish@gsfc.nasa.gov)

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