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SCIENCE TEAM MEETINGS

SCIENCE ARTICLES

ANNOUNCEMENTS

EDITOR'S CORNER

Michael King
EOS Senior Project Scientist

I'm pleased to announce the availability of the new EOS Project Science Office web site, the primary science and education reference site for the EOS program. We have upgraded the look, content, and usability of the site to better serve the EOS community. This complete redesign clearly distinguishes information intended for science users, education users, news media, and the general public. New additions of note are the EOS Message Boards, EOS Web Newsletter, and weekly EOS news stories and research highlights covering the status of our missions and new research accomplished under the auspices of EOS. The site also includes a new interface for searching the EOS Directory, with more robust query capabilities for the 6700+ entries in the database. The EOS Reference Handbook, Data Products Handbook, Science Plan, mission profiles, and the entire archive of Earth Observer Newsletters are available. The new EOS Project Science Office web site is a valuable resource for the EOS community and beyond, and I encourage you to take a look, and provide any comments on its content or organization. The URL is http://eos.nasa.gov/.

A major step was achieved in Aqua mission preparations, with the completion of electrical integration of all instruments onto the Aqua spacecraft. Some minor science data interface problems are being addressed with MODIS and CERES, but those are expected to be corrected in the near future. Meeting the December 21 launch date will be difficult, in view of the extra time needed to handle a variety of unexpected complications that arose during the electrical integration. Regardless, plans are proceeding for a launch this calendar year. A pre-launch aircraft campaign for validation of the AMSR-E sea ice algorithm is taking place through July 6, 2000. This campaign will use NOAA microwave radiometers on a Navy P-3 aircraft flying out of Thule, Greenland, to collect data to be compared with satellite retrievals from the DMSP SSMI, using algorithms similar to those

(Continued on next page)

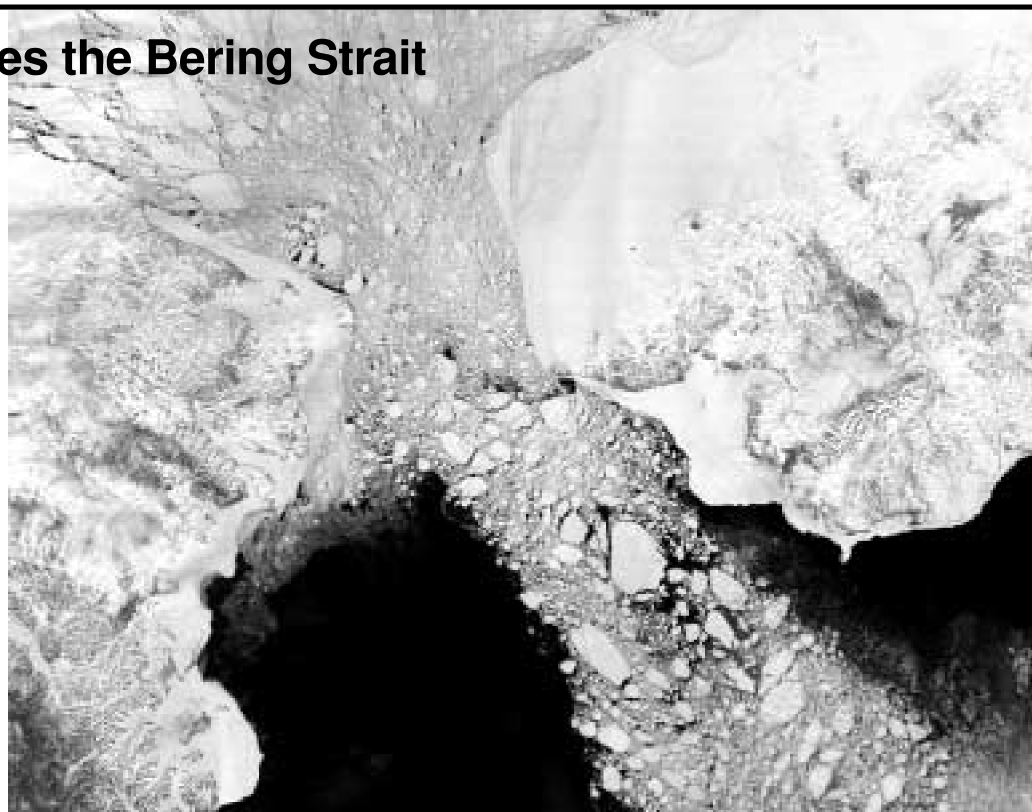
developed for the AMSR-E. This is the first of several planned aircraft validation campaigns for the AMSR-E sea ice algorithms and is focused specifically on determining the impact of summer melt conditions on the satellite-derived sea ice concentrations.

The U.S. component of the Ozone Monitoring Instrument (OMI) International Science Team has been selected as part of a NASA Research Announcement. OMI is a joint U.S.-Dutch-Finnish venture, and will be flown on the EOS-Aura satellite in June 2003. Dr. P.K. Bhartia, a recognized leader in ozone research at Goddard Space Flight Center, has been named as the U.S. OMI Science Team Leader. Under his leadership, the U.S. Science Team members will develop algorithms for retrieval of atmospheric trace gases and instrument calibration/validation required to produce valuable science data products. Of the 14 proposals awarded, 10 were for algorithm development, and 4 were for instrument characterization and validation. The fourth OMI science team meeting was held in the Netherlands in June. This was the first time the newly selected U.S. OMI Science Team members participated. Participants were organized into five working groups including algorithm development and calibration/validation, which are chaired by Science Team members from different countries. These events combine to represent significant developments in a key element of the EOS program's science objectives.

On May 10 and 11, a management meeting between NASA and the Russian Space Agency (RSA) was held to discuss the status of the Meteor 3M/SAGE III mission. The NASA delegation included representatives from NASA Headquarters, Langley Research Center, and Goddard Space Flight Center. After intensive discussions, a tentative launch date of December 15, 2000 was agreed on, pending successful spacecraft integration and testing. NASA had planned to ship the SAGE III flight hardware to Russia on June 15, but the shipment has been delayed due to concerns over contamination of the Meteor 3M spacecraft facility. The shipment of the SAGE III instrument will resume as soon as new air filters are installed in the spacecraft facility.

Finally, I'm happy to report that Dr. Peter Hildebrand has been named as the new Aqua Deputy Project Scientist. He will be focusing on Aqua Validation activities. Also, Steve Graham has been named the Aqua Outreach Coordinator. I'm confident that these two key additions to the Aqua team will contribute to a very successful mission.

Spring Ice Chokes the Bering Strait

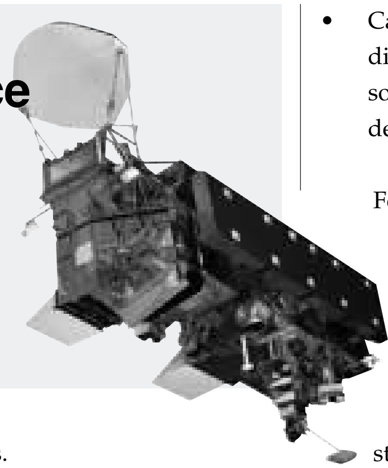


MODIS image of the Bering Sea, Bering Straight and southern Arctic Ocean acquired May 7, 2000. Image generated from MODIS band 2 (0.85 µm) at 250 m spatial resolution. Detailed structure and leads in the ice pack are apparent. Ice flow from the Bering Strait southward to the Bering Sea is seen in great detail.

George Riggs, NASA GSFC

Minutes of the Aqua Science Working Group Meeting

—Steve Graham (steven.m.graham.2@gsfc.nasa.gov)
Aqua Outreach Coordinator



The Aqua Science Working Group met at the Goddard Space Flight Center (GSFC) on April 27, 2000. Claire Parkinson, the Aqua Project Scientist, opened the meeting at 8:30 by welcoming everyone and introducing the new Aqua Outreach Coordinator, Steve Graham, of the EOS Project Science Office.

Parkinson began by stating that considerable progress has been made since the last meeting, which occurred in October 1999. The MODIS, AIRS, HSB, and AMSR-E instruments have all arrived safely at TRW, and those along with the previously ready CERES and AMSU instruments were all mechanically integrated onto the spacecraft between December 15, 1999 and February 1, 2000. Electrical integration of the instruments is now underway. Last fall, the AMSR-E and AIRS/AMSU/HSB Algorithm Theoretical Basis Documents (ATBDs) were updated, and on March 14, 2000 they were defended before a review panel. The NRA for AIRS/AMSU/HSB and AMSR-E Validation has been approved and signed by Ghassem Asrar and is scheduled to be released on May 8, 2000.

Next, a short discussion took place regarding the newly approved minimum success criteria for the Aqua mission. These criteria state that a successful Aqua mission will:

- Achieve a safe launch and on-orbit check-out of the spacecraft and instruments.
- Produce the first high spectral resolution global infrared spectra of the Earth.
- Obtain 1 K/1 km global root-mean-square temperature profile accuracy in the troposphere by 1 year after launch.
- Extend the improved TRMM rainfall characterization to the extra tropics, for a minimum of one year.
- Produce the first global, through-clouds SST daily maps of the ocean, for a minimum of one year.
- Produce large scale global soil moisture distribution for regions with low vegetation.
- Produce calibrated global observations of the Earth's continents and ocean surfaces 150 days after the mission is declared operational.
- Capture and document three seasonal cycles of terrestrial and marine ecosystems and atmospheric and cloud properties.
- Produce three sets of seasonal/annual Earth radiation budget records.
- Produce improved measurements of the diurnal cycle of radiation by combining Aqua measurements with Terra and/or TRMM measurements for months of overlap.
- Produce combined cloud property and radiation balance data to allow improved studies of the clouds in the climate system.
- Capture, process, archive, and distribute Aqua data products, doing so by 150 days after the mission is declared operational.

Following Parkinson's opening remarks, Bruce Barkstrom, the CERES Team Leader, provided an update on the CERES program. Barkstrom began his talk with an overview of the CERES Science Objectives, stating that for climate change analysis, there must be a continuation of the ERBE record of radiative fluxes at the top of the atmosphere (TOA) and that the same analysis techniques performed on the ERBE data must be used for Aqua (as is being done for Terra) and that much of the software is based on the same code for ERBE data. Other objectives include doubling the accuracy of estimates of radiative fluxes at TOA and the Earth's surface, providing the first long-term global estimates of radiative fluxes within the Earth's atmosphere, and providing cloud property estimates consistent with the radiative fluxes from surface to the top of the atmosphere.

Barkstrom then displayed preliminary data/images from the Terra press conference held on April 19, 2000. He noted that within a few days of Level 1B, the CERES team was producing Level 2 data using ERBE angular distribution models, getting about 10% albedos over the ocean, 25% over the Sahara, and 70% on the tops of the highest thunderstorms. In addition, the data are correctly geolocated and the team is reasonably happy with the progress of the instrument.

The CERES S'COOL Project now has over 465 schools in 36 countries providing ground-truth measurements of clouds to assist with the validation of the CERES instrument.

Next, Kory Priestley of the CERES Team presented on the CERES Deep Space Maneuver. He reminded the audience that CERES is two instruments, one predominantly for cross track spatial sampling (Fixed Azimuth Plane Scanning), the other for hemispherical sampling (Rotating Azimuth Plane Scanning). Both CERES instruments can operate in either mode.

Priestley remarked that there is a need to characterize scan dependent offsets, which are extraneous instrument artifacts that impart sample dependent biases on the radiometric measurements. These offsets arise from two sources, electromagnetic signals and micro-strains. Priestley noted that the offsets are very significant and that accurate knowledge of scan dependent offsets at the sub 1-count level is necessary to meet the mission accuracy requirements of 0.5% and 1.0% accuracy for terrestrial and solar energy flows. Globally averaged this roughly corresponds to flux values of 1.2 W/m^2 top of the Atmosphere LW Flux and 2.0 W/m^2 TOA SW Flux. By taking the total channel and subtracting the shortwave channel, it's difficult to meet the error budget; but by doing the pitch-over maneuver, the errors can be removed.

Next, Priestley provided an overview of the lessons learned from TRMM. He noted that ground to on-orbit shifts of approximately 1 count peak-to-peak occurred in all three channels of the CERES PFM instrument; analyses of the collected data indicated that 30-50 repetitions of each combination of elevation and azimuthal angle are necessary; and CERES/TRMM scan dependent offsets have been reduced an order of magnitude from ERBE. As a bottom line, Priestley stated that a significant improvement has been made over ERBE; CERES accuracy requirements are a factor of 2 more stringent than ERBE; offsets are still significant as potential error sources for CERES; and TRMM should only be viewed as a "best case" until the design is validated over several flight models.

Following the TRMM discussion, impacts of Terra omitting and/or delaying its CAMs was discussed. An immediate impact would be that the traceability to ground calibration radiometric scale would be less certain. There would also be a significant impact on validation timeline for the Level-1 data which would then impact all downstream data products.

Priestley concluded his presentation by summarizing the pertinent issues, noting that it is imperative that CERES accurately characterizes their scan dependent offsets in order to achieve their scientific goals and continue the long term dataset. A failure to do this would mean a significant impact to the data validation timeline, a delay in the release of validated data products, more frequent reprocessing, less certain intercalibration with similar instruments, and a degraded ability to monitor long-term climate change.

Vince Salomonson, the MODIS Team Leader, opened his presentation by displaying early images from MODIS-Terra and noted that many of the images are located on the Terra Homepage URL at terra.nasa.gov. In addition, a MODIS poster that was displayed at the Investigators Working Group meeting recently held in Tucson, AZ was also presented. Salomonson walked through a series of images that highlighted many of MODIS' capabilities including sun stimulated fluorescence, natural color imagery, comparisons between AVHRR and MODIS, ocean color, cloud optical thickness, total column water vapor, land composites, sea surface temperature, aerosol optical thickness, and broadband white sky albedo. Salomonson added that one of the things not yet illustrated well is the fire band. There is a large dynamic range on the intensity of fires within a pixel up to 400K, and the team has not yet come up with a good illustration of how well they are doing this. But overall, MODIS is performing "better than spec" providing useful data in several areas.

Pre-launch calibration and characterization was critical to the development and the ultimate use of the MODIS data. Even though very considerable efforts were provided by the MODIS MCST that have improved the performance of the MODIS, there was more that should have been done. The pre-launch test program still was not sufficient to adequately identify and characterize some key sensor problems (focal plane co-registration, ADC/bin-fill non uniformity, mirror side differences). Also, major compromises were made to the Terra-MODIS in order to adhere to an earlier (not achieved) launch schedule including not verifying an electronic cross-talk fix (the problem still persists), and not measuring the RVS of the scan mirror. In addition, fixes of known problems on FM1 may not be made due to similar launch schedule pressures.

The test schedule for Terra operations was too tight and if there are similar assumptions for Aqua, launch readiness will be compromised. The duration of A&E phase was underestimated, as 90 days was not adequate. At L+132, the deep space maneuver had not been conducted, the solar diffuser only finished on L+131, the sensor is not in optimal operational configuration and is still requiring TDRSS support for real-time operations. Salomonson added that a more realistic schedule is needed for Aqua.

The telemetry specification for Level 0 data from Aqua is not finalized.

Salomonson assumes that this will not be significantly different than Terra, but if it is, then Aqua Level 1a software will not be ready for launch. Also, bit flips in the data from the Terra spacecraft caused problems with EDOS and DAAC processing of the data.

Funds for Aqua processing hardware must arrive by L-5 months because the current MODAPS will be unable to support production of both Aqua and Terra products at the required volumes and resources will severely limit testing of Aqua processing.

After a brief break the meeting reconvened with Parkinson summarizing the October 15, 1999 Agreement on the Aqua Spacecraft Maneuvers during the first 90 days after launch. This agreement stated that:

- The deep-space maneuver will be a constant-pitch-rate maneuver done on three consecutive orbits, preferably on day 55 or as soon thereafter as the moon is out of the way.

- A series of yaw maneuvers with the MODIS doors closed will be done on days 26-27, and a second series of yaw maneuvers with the MODIS doors open will be done on days 30-31.

- A small roll maneuver, to enable a view of the moon from the MODIS Space View Port, will be done on day 40 or as soon thereafter as the moon is appropriately positioned.

Dr. Mous Chahine, the AIRS Team Leader, then stated that the deep space maneuver should be removed from the schedule because it will cause a reduction in data quality from the AIRS, which would take considerable time to correct itself. He said that George Morrow has been informed of the AIRS team viewpoint.

Parkinson then turned the floor over to Fran Wasiak of Aqua's Instrument Planning Group to discuss the Integrated Mission Timeline (IMT). The purpose of the IMT is to plan the order of the activities necessary to get the spacecraft to the operational phase of the mission and is intended to be a high-level management tool. The IMT was developed largely from TRW's Orbital Activation Plan and includes information acquired at the October 1999 Science Working Group meeting. A preliminary IMT Review was held on February 29-March 2 and included Aqua Project, TRW, Instrument Operation, and Flight Operation Teams. Inputs from this review are being incorporated and a new version of the IMT is scheduled to be released at the end of May. It will be accessible at the following internet address: ftp://198.118.192.20/pub/fot/leo_timelines/pm

After returning from lunch, Roy Spencer, the AMSR-E Team Leader, offered an update on AMSR-E Validation and Science. A joint AMSR Science Team Meeting will be held in July 2000 in conjunction with the IGARSS meeting in Honolulu, HI.

Validation plans for AMSR rainfall products in FY 2000 include the routine operation of Eureka WSR-88D (doppler radar) and the installation of rain gauge clusters at 2 locations (tbd). In FY 2001, in addition to the routine operations of the WSR-88D, the Wallops Experiment on 3D raincloud structure will occur and will include 2 multi-parameter radars, NASA NPOL radar, NOAA ETL radar, rain gauge and disdrometer network. In FY 2002, an experiment will be conducted in the Sea of Japan which will include the NASA NPOL radar, DC-8 with radiometers, NASDA radars and microphysics aircraft, NASDA ground support, and possibly the ER-2 with radiometers. In FY 2003, a long-term statistics program will start (possibly at Wallops) with the NPOL radar, and in FY 2004 a 60-day Eureka experiment with 2 aircraft is planned.

Validation plans for AMSR ocean products include the utilization of buoys, ships, and satellite radiometers for SST; buoys, satellite radiometers, and NCEP models for surface winds; radiosondes for integrated water vapor; histogram analysis and GOES imagery for integrated cloud water.

Validation plans for AMSR land products include field experiments that will utilize intensive sampling over a 200 x 200 km area diverse in vegetation, climate, and topography, for a 1 month period, employing satellite, airborne, and ground instrumentation. In addition, existing operational networks will be utilized such as the Oklahoma Mesonet, DoE ARM/CART, USDA ARS Micronet, Illinois Climate Network, and sites in Russia, China, and Mongolia. Also, cooperative programs such as GEWEX/GAME, GEWEX/CEOP, GSWP, DAO, NCEP, and ECMWF will be leveraged. Comparisons with other sensors such as the SSM/I and SSM/IS, Aqua's MODIS and AIRS, and SAR will be studied. Field campaigns currently scheduled include Nagaoka, Japan (2000), Southern Great Plains (2001, 2003, 2005), Walnet Creek, IA, Little River Watershed, GA, San Pedro basin, AZ, and Thailand, Tibet, and Mongolia in 2001-02 (with NASDA).

Sea ice validation plans include satellite intercomparisons with SSM/I and SSM/IS and campaigns such as Meltpond 2000 in the Arctic (June/July 2000), and campaigns in Antarctica (August 2001, 2003 out of Punta Arenas) and the Arctic (with rainfall experiments in 2002 and 2004). Snow cover plans include participation in MODIS field campaigns, AMSR-E sea ice campaigns, and an NSIDC collaboration.

The second half of Spencer's talk dealt with AMSR-E science. It was noted that cloudy SST retrievals from the TRMM microwave imager (TMI) have been demonstrated. Examples included how the TMI shows cold wakes behind hurricanes that AVHRR misses, and how TMI SST's and QuikScat winds show mesoscale modulation of winds by equatorial instability waves. In addition, pointing errors have been found in NOAA K AMSU data (window channel imagery), as evidenced by the continents moving back and forth on the imagery. Aerojet has documentation of measured AMSU pointing errors and NESDIS has documentation of AMSU mounting errors.

Following Spencer's presentation, George Aumann, the AIRS Project Scientist, presented a status update on the AIRS/AMSU/HSB Program. Aumann stated that the instruments are mounted on the spacecraft and mechanical alignment is completed. Detailed on-orbit sequence from launch to launch + 90 days has been developed. In addition, a high level plan for data processing/validation from launch to launch +12 months is being synchronized between the GSFC DAAC and the AIRS science team.

Characterization of the AIRS at spectrometer temperatures of 149K, 155K, and 161K were completed in thermal vacuum testing before shipping. The temperatures were selected based on the predicted range of orbital conditions.

Aumann noted that instrument performance is "on spec" and the radiometric accuracy, after accounting for linearity, scan angle and polarization effects using the thermal vacuum data, is expected to be excellent.

Analysis of test data to determine the spectral response function (SRF) for each detector is almost completed. Part of the SRF determination involves high resolution measurements of the entrance filter for each array at 149K, 155K, and 161K using spare filters at JPL. Ten of the eleven entrance filters have been tested to date.

The AIRS SRFs are critical for the quantitative use of the AIRS data. The SRFs will be made available as part of the AIRS Calibration Report for external users. Aumann said that there are two methods which make the SRF details transparent to the user:

1. If the user prefers his/her own radiative transfer, then the SRF for each of the 2378 spectral channels is given by a prescription (available in tabulated form and as a function call).

2. If the user prefers the AIRS team-provided radiative transfer routine, giving the atmospheric/surface state vector as input to a function call returns the calculated upwelling spectral radiances for each of the 2378 spectral channels as output.

After a short break, EOS Validation Scientist David Starr provided an overview of the 2nd EOS Validation NASA Research Announcement (NRA). This NRA is limited to AIRS and AMSR-E on Aqua, and a few spectroscopic studies supporting Aura and will distribute approximately $2M per year, excluding the Atmospheric Radiation Measurement Radiosonde program. Teams and program managers from NASA Headquarters are expected to participate in the proposal review process and are also expected to organize post-selection workshops to initiate contact with the selected investigators.

The NRA is due to be released on May 8; letters of intent due June 15; proposals due July 13; peer review by mail due September 11; peer review panel will convene September 26-28; and selections will be released on November 1.

An open re-competition for CERES and MODIS is planned, with the possibility of a few additional Terra (ASTER, MOPPIT, and MISR) and maybe IceSat (GLAS) investigations. Current plans are to extend the proposals one year and then have a recompetition with selections by September 1, 2001 (draft NRA by October 2000). Starr wants input from the CERES and MODIS teams so he can develop an effective NRA for the next cycle.

Following Starr's presentation, Aumann offered some thoughts on Aqua platform instrument cross-validation. He noted that validation of a product means certifying that the product measures what it is intended to measure and has a quantifiable accuracy. Comparison of measurements of the same spatial, spectral, and temporal scene from two separate instruments on Aqua does not constitute validation, but may only confirm that data from two instruments are statistically likely to refer to the same quantity.

Aqua instrument cross-validation must be timely. There are significant differences in the maturity of the software of the different instruments. However, after significant bugs are fixed (e.g., L+3 months) every effort should be made to complete some level of cross-validation before the software is officially labeled "validated" (e.g., L+12 months) and available to the outside investigators from the DAAC.

Cross validation will be very useful and can be done in a timely fashion if limited to simple products (Level 1B) and simple scenes. Cross validation within the first 12 months is not practical for global comparisons and Level 2. After then the comparison of apparently similar named products from different instruments can be a fruitful research effort.

Aumann suggested to have each instrument team evaluate potential areas for cross validation, coming to an agreement on what should be done and when, and present the plan at the September 2000 Aqua Science Working Group Meeting.

The final presentation of the meeting was given by Claire Parkinson and Steve Graham on Aqua outreach. It was noted that for the Terra mission, a set of science fact sheets were prepared that highlighted the science themes of the mission, and these topics were displayed for the group to discuss. It was proposed that the Aqua mission also develop a set of fact sheets highlighting its science. Parkinson and Graham presented the following list of four possible topics:

- The Aqua Mission
- The Water Cycle
- Enhanced Weather Forecasting
- The Earth's Snow and Ice Cover

The group decided that the fact sheets should be written for the water cycle and enhanced weather forecasting first and, upon the recommendation of Larrabee Strow, that one or more of the fact sheets should emphasize new technologies.

Finally, the possibility of performing a "webcast" of the Aqua launch was discussed. The suggestion was well received, and preparations will begin regarding this event. The meeting concluded at 4:00pm. The next scheduled Aqua Science Working Group Meeting is September 12, 2000 at GSFC.

New Multiangle Imaging SpectroRadiometer (MISR) Data Available

— Linda A. Hunt (l.a.hunt@LARC.NASA.GOV), NASA Langley Atmospheric Sciences Data Center

The Earth Observing System Data Information System (EOSDIS) NASA Langley Atmospheric Sciences Data Center (Langley DAAC) announces the release of Multi-angle Imaging SpectroRadiometer (MISR) Level 1 data. These include Level 1 raw imagery (Level 1A); radiometrically calibrated imagery (Level 1B1); geolocated, co-registered, map-projected imagery (Level 1B2); browse data; and geometric parameters on a swath-by-swath basis. Engineering, navigation and on-board calibrator files are also available, along with static data sets that provide parameters needed to convert the image data to physical radiances or to establish geodetic latitudes and longitudes and surface elevations. These data sets are available through the Data Center's home page URL: eosweb.larc.nasa.gov

Follow the "Access Data" link and select the MISR project to view project and data set information and to link to the search and order tool.

MISR is part of NASA's Terra spacecraft, launched into sun-synchronous polar orbit on December 18, 1999. MISR measurements are designed to improve our understanding of the Earth's environment and climate. Viewing the sunlit Earth simultaneously at nine widely spaced angles, MISR provides radiometrically and geometrically calibrated images in four spectral bands at every angle. Spatial sampling of 275 and 1100 m is provided on a global basis.

For information regarding NASA Langley Atmospheric Science Data Center data, or for assistance in placing an order, please contact:
NASA Langley Atmospheric Sciences Data Center
Science, User and Data Services
Mail Stop 157D, 2 S. Wright Street
Hampton, VA 23681-2199
Phone: 757-864-8656
Fax: 757-864-8807
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CERES Science Team Meeting

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

The 21st Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held in Hampton, VA on May 2-4, 2000. The team decided that Edition 2 ERBE-like (ERBE is the Earth Radiation Budget Experiment) Tropical Rainfall Measuring Mission (TRMM) data are ready to archive. The Edition 1 Single Satellite Footprint (SSF) TRMM data product is in good shape, with only a few changes needed before starting archive and distribution in about two months. The next Science Team meeting is scheduled for September 20-22, 2000 at the University of Alabama-Huntsville.

Bruce Wielicki (LaRC), CERES Co-Principal Investigator, opened the meeting with an Earth Observing System (EOS) program status report. The official Aqua launch date is December 2000. He also briefed the team on a recent NASA exercise to establish a vision for the next 25 years of Earth Science space missions and technology needs.

CERES Instrument Status

Larry Brumfield (LaRC) presented the Aqua instrument status report. The CERES instruments were delivered to the Aqua spacecraft in early January, mounted onto the spacecraft, and are ready for integration and testing. Kory Priestley (LaRC) delivered the CERES/Terra Flight Models 1 & 2 (FM1 and FM2) validation status report. Early results demonstrate ground-to-flight radiometric stability of better than 0.5, 0.4, and 0.25% for the window (WN), shortwave (SW), and total channel pairs of radiometric sensors. Coastline detection algorithms demonstrate mean navigational accuracies at the 1-km level. Three-channel intercomparison, and deep convective albedo studies suggest the Terra and TRMM instruments are on the same radiometric scale with confidence bounds at the sub 1% level.

Richard Green (LaRC) presented Tropical Mean intercomparison results for March 2000 showing consistency between the FM1, FM2, and TRMM Proto Flight Model (PFM) at the 0.5% level for nighttime LW and at 0.1% between FM1 and FM2 SW. Martial Haeffelin (Virginia Tech) highlighted preliminary results from TRMM/Terra matched view zenith/relative azimuth intercomparison studies. The CERES instruments on the two spacecraft are in agreement to within 0.4% and 0.5% for SW and longwave (LW) radiance, respectively.

Kory Priestley summarized operations for the TRMM PFM instrument's return to service. Operational power was restored on February 25, 2000 and nominal science data collection in the cross-track mode was begun February 26th. Attempts to transition to biaxial operations saw sluggish azimuth gimbal performance; recovery operations to exercise the gimbal were completed in mid-March. Beginning on March 13th the primary science channel output began experiencing 'contamination' from an unknown electronic source. Suspicion lies with the failing Interpoint voltage converter. Diagnostic studies are underway. Initial results suggest that the data are recoverable, and that the noise can be eliminated in future data collection.

Bruce Barkstrom (LaRC), CERES Co-Principal Investigator, discussed the need for deep space observations on Terra and Aqua. CERES has sample-dependent offsets, and the only rigorous approach to determining offsets is observation of deep space. However, other instruments on Terra and Aqua have some concerns about making deep space observations. The team for ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) on Terra is worried about solar incidence, and the team for AIRS (Atmospheric Infrared Sounder) on Aqua is concerned about thermal stability of calibrations.

CERES Data Systems

Bruce Barkstrom highlighted two new data system issues. First, the Earth Science Enterprise (ESE) recently announced that it would implement recovery of the full marginal cost of data products. Second, the ESE is proceeding to explore long-term archiving of EOS data with NOAA.

Jim Kibler (LaRC) updated the team on the Instrument Simulator, a new version of the view_hdf tool, data and code deliveries, and data product versions. The TRMM and Terra simulators are operational and are being used for testing and validation of command sequences, scan tables, software patches, and long command uploads. The Aqua simulator is under development. Dealing with the TRMM and Terra data flow has been a challenge, but the team is identifying the problems and successfully handling the large volume of data.

CERES/TRMM ERBE-like Data Products

Kory Priestley presented the final spectral response functions used in the Edition 2 ERBE-like products. David Young (LaRC) reviewed recent algorithm improvements and the current status of the ERBE-like products. The Edition 2 ERBE-like TRMM data are ready to archive and release with the updated data quality summaries.

CERES/TRMM SSF Data Product

Patrick Minnis (LaRC) summarized recent changes to the CERES cloud algorithm including a variety of improvements in nighttime and twilight retrievals and a new five-band application of correlated k distribution techniques to account for atmospheric absorption across the Visible Infrared Scanner (VIRS) and Moderate-Resolution Imaging Spectroradiometer (MODIS) 3.7 µm bands. He presented comparisons of cloud properties derived using European Center for Medium-Range Weather Forecasts (ECWMF) and GSFC's Data Assimilation Office (DAO) data in the Meteorological, Ozone, and Aerosol (MOA) data base. He presented an extensive set of cloud property validation data sets and consistency checks. Results from the integration of Ron Welch's methods for determining cloud cover, aerosols, and smoke were shown. An intercomparison of cloud properties derived using techniques of Minnis, Jim Coakley (Oregon State University [OSU]) and Qingyuan Han (University of Alabama–Huntsville, [UA-H]) was presented. Tom Charlock (LaRC), Norman Loeb (Hampton University [HU]), and David Kratz (LaRC) showed results which confirmed the validity of the SSF clear-sky fluxes; however, several problems with the cloudy-sky fluxes were noted.

The team concluded that several changes are needed prior to archiving the TRMM Edition 1 SSF data product. The calibration of the 1.6 µm VIRS channel should be changed to be consistent for both the cloud algorithm and aerosol optical depth (AOD) retrieval. A channel 1 reflectance variability test will be added to remove sub-pixel cloud contamination from the 2-km VIRS pixels used to determine cloud optical depth. Three new parameters will be added: fraction of VIRS pixels and average reflectance of VIRS pixels (0.63 and 1.6 µm) in the CERES field of view (FOV) used to determine the AOD. A 10-minute land/water mask will be used instead of the 2.5-degree mask to avoid eliminating many AERONET validation sites. Minnis, Coakley, and Han will intercompare radiative model calculations at 3.7 µm to resolve particle size method retrieval differences.

The team decided that, in addition to the cloud and aerosol retrievals, only the clear-sky fluxes should be included on the SSF. More TRMM scanner data are required to develop the new angular models for cloudy conditions. Meanwhile, users will have improved (relative to ERBE) cloud screening and clear-sky fluxes. Clear-sky will be defined as 0% cloudy pixels in the FOV.

Cloud Working Group

Patrick Minnis led discussions of cloud retrieval, archival, and validation issues. The group agreed that cloud fraction and cloud pressures were ready for the first archiving of cloud property retrievals. Optical depth, water path, and particle sizes were also recommended for archiving, but with the caveat that these properties during twilight and nighttime hours should not be considered as reliable. Coakley, Minnis, and Han will compare their respective radiative transfer calculations to eliminate the possibility that the radii differences are due to model differences. Larry Stowe (NOAA) led a discussion of initiating further screening of the clear-sky aerosol data to eliminate cloud contamination.

Ron Welch (UA-H) demonstrated a new version of the satellite data display and analysis tool Interactive Visual Image Classification System (IVICS). He presented several analyses of VIRS data using IVICS and his image classification methods that utilize neural network techniques. Mike Friedman (OSU) gave a progress report on pixel-scale water cloud retrievals. He identified mid-latitude water clouds as having the largest particle size differences between their retrieval and those retrieved with the CERES cloud algorithm. Han analyzed variations in ice cloud property retrievals due to phase functions that are assumed in the modeling process. He discussed the sensitivity of the retrievals to assumed particle size distributions, shapes, and aspect ratios.

Kazuaki Kawamoto (Virginia Tech) discussed improved techniques for the nighttime CERES cloud algorithm to allow retrieval of cloud properties when temperature inversions are present. Xiquan Dong (University of Utah) summarized CERES cloud property validation activities using surface data taken at the SHEBA (Surface Heat Budget of the Arctic) ship during the Arctic Cloud Experiment (ACE) and for 2 years of data taken at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site. Ben Ho (Analytical

Services & Materials, Inc. [AS&M]) compared liquid water path (LWP) retrievals from coincident VIRS and TRMM Microwave Imager (TMI) data. Seiji Kato (HU) showed that VIRS-derived LWPs were larger than those derived with a technique that combines radar and microwave radar data over the ARM SGP site.

Surface and Atmospheric Radiation Budget (SARB) Working Group

The meeting was led by Tom Charlock and David Kratz. David Rutan (AS&M) presented the new on-line database for the CERES ARM Validation Experiment (CAVE) which was developed to facilitate validation of CERES-derived surface fluxes. It consists of flux measurements from ARM, BSRN, and other high-quality surface sites from around the world which are matched in space and time with satellite retrievals. David Kratz compared CERES surface LW fluxes obtained from the surface-only LW model developed by Shashi Gupta with measurements from several ground sites. Kratz identified physical causes for the large differences observed at some sites and known instrument maintenance problems at other sites.

V. Ramanathan (Scripps Institution of Oceanography [SIO]) presented results of CERES validation with measurements obtained from the Indian Ocean Experiment (INDOEX). These measurements were made at the Kaashidhoo Climate Observatory (KCO) in the Republic of Maldives. CERES TOA albedos were in good agreement with theoretical estimates at the KCO for solar and view zenith angles less than 50 degrees. Aerosol radiative forcing (ARF) efficiency was estimated to be about –25 Wm^{-2} per unit AOD. ARF efficiency increased with solar zenith angle and varied from -24 to -28 Wm^{-2} per unit AOD.

Charlock described the ongoing effort to measure spectral SW reflectances of the ocean surface at the CERES Ocean Validation Experiment (COVE) site, a Lighthouse platform in the Atlantic ocean off the coast of Virginia. Measurements are made with a Schulz spectrophotometer. The results are being used to develop new spectral bidirectional reflectance distribution functions (BRDFs) for the ocean surface, and to validate the BRDFs being used in CERES processing.

Fred Rose (AS&M) presented results of recent improvements to the Fu-Liou radiative transfer code. The changes include improved treatment of Rayleigh scattering, ozone and aerosol extinction, and surface albedo. William Collins (NCAR) presented results of a global assimilation model which may provide estimates of AODs for use in SARB processing. Yaping Zhou (AS&M) presented results on spectral fluxes and 31 BRDFs obtained during the CERES ARM Radiation Experiment (CARE) conducted at the ARM SGP site in August 1998. These measurements were made by a spectral radiometer flying on a helicopter at a height of 300m over several types of cropland. The measurements were reduced to surface and TOA BRDFs by applying atmospheric corrections. Comparisons of measured and derived upwelling and downwelling fluxes showed good agreement.

Angular Distribution Model (ADM) Working Group

Norman Loeb led the ADM working group meeting with a general overview of critical ADM/inversion research issues. Dave Doelling (AS&M) presented results from an ongoing study that seeks to account for changes in regional cloud amount between CERES broadband measurements using 3-hourly geostationary measurements. Nitchie Smith (AS&M) presented cloud-free LW and WN limb darkening functions obtained from CERES data. She examined the sensitivity of the ADMs to precipitable water, lapse rate, and surface temperature. Using CERES SSF data, Loeb examined the influence of variable FOV size on the all-sky mean albedo from CERES VIRS12 ADMs. ADM-derived albedos showed a 10% decrease with viewing zenith angle, likely due to the variable footprint size. Removal of this viewing zenith angle bias in the all-sky albedo may require a redefinition of ADM scene types which have a frequency of occurrence that is independent of viewing zenith angle.

Investigator Presentation Highlights

Robert Cess (State University of New York at Stony Brook) presented results from a study of the impact of El Nino on cloud radiative forcing (CRF) over the warm pool region. He compared CERES-derived SW and LW CRF for Jan-Aug 1998 with corresponding ERBE-derived values for the same months in 1985-89. The SWCRF/LWCRF ratio, which was close to unity for the ERBE years, was considerably higher (about 1.3) for 1998. Cess hypothesized that deep convective clouds over the warm pool region thicken during El Nino episodes leading to stronger SWCRF.

Si-Chee Tsay (GSFC) presented results from a study of thermal characterization of pyranometers and pyrgeometers used in surface and atmosphere energetics measurements. He outlined the role of these instruments in climate research and in validating satellite retrievals of surface radiative fluxes and emphasized the importance of the absolute calibration for establishing accurate long-term trends.

Marat Khairoutdinov of Colorado State University, (CSU) (representing David

Randall) compared CSU General Circulation Model (GCM) simulations of TOA radiation fields with corresponding CERES measurements of reflected SW and outgoing LW fields. The radiation module in the CSU GCM has been replaced by a new module which is based on the Fu-Liou radiation code and uses anomalous diffraction theory.

Bryan Baum (LaRC) presented early results on cloud properties retrieved using data from MODIS. He compared MODIS retrievals of cloud amount, height, optical depth, and drop size distributions obtained for the March 2000 IOP over the ARM CART site with similar results derived from GOES data.

Tom Charlock (LaRC) presented methodology and results of an effort to retrieve surface albedo from CERES/TRMM data. He outlined the retrieval procedure and listed the factors that affect the results. He listed AOD as one of the most important and least certain factors. Charlock presented results from the CARE experiment conducted during August 1998 near the ARM SGP site which showed an increase in broadband surface albedo with solar zenith angle.

Jim Coakley (OSU) determined direct ARF from data obtained during the INDOEX. AODs derived from AVHRR data using the 2-channel method were compared with observations. He showed relationships between AOD and direct ARF and the changes in AOD from March 1996 to the present. CERES-derived ARF was generally higher than AVHRR values.

Ron Welch (UA-H) presented results from a study of biomass burning and smoke ARF over South America and Africa using TRMM data. Smoke pixels were identified from VIRS data, and smoke AOD and single scattering albedo were retrieved for these pixels. Satellite retrievals were used to construct smoke ADMs and estimate smoke ARF.

Larry Stowe (NOAA) showed that AODs derived from VIRS channel 1 using CERES SSF data were about 0.05 higher than those from AVHRR channel 1. The range of AODs derived from AVHRR was much wider. Retrievals from channels 1 and 2 of VIRS were found to be consistent with each other. AODs from VIRS data were found to be higher than those from AERONET observations.

Steven DeWitte (Royal Meteorological Institute, Belgium) presented status reports on two instruments currently measuring total solar irradiance and the Geostationary Earth Radiation Budget (GERB) instrument which will be flown on the Meteosat Second Generation (MSG) satellite later this year. The development of GERB processing systems, which draw heavily on the corresponding CERES systems, is on schedule.

Bing Lin (HU) presented results of a study of the variations of cloud amounts over the tropical western Pacific and tropical eastern Pacific derived from multiple sensors on the TRMM. Lin found almost no relationship between total cloud amount and the southern oscillation index. Better correlations were found when cloud amounts in low, middle, and high layers were examined separately.

Takmeng Wong (LaRC) presented results from a stochastic quality assurance algorithm applied to the 14-year record of ERBE non-scanner data. This algorithm minimizes errors in satellite-derived global fields caused by inadequate temporal sampling.

Anand Inamdar (SIO) examined the interannual variability of the atmospheric greenhouse effect (G_a) for the window and non-window regions using Nimbus 7, ERBE, and CERES data. He also examined the relationship between surface temperature and G_a over tropical oceans.

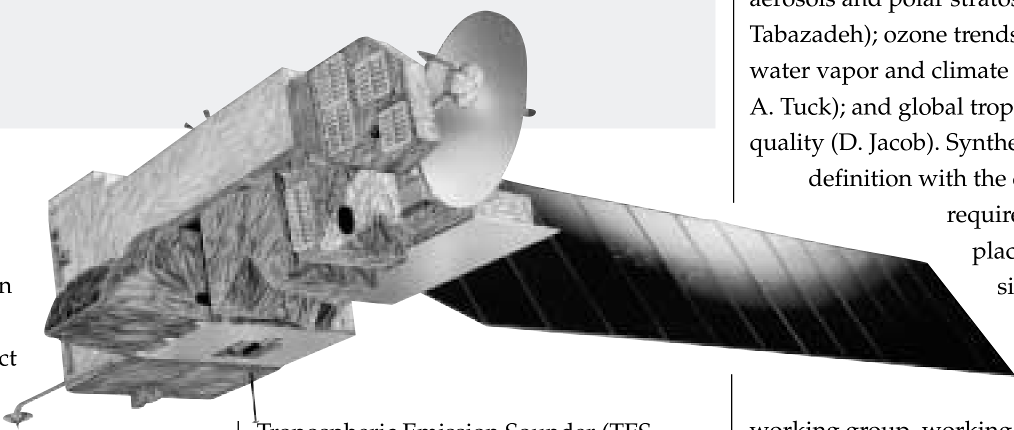
Shi-Keng Yang (NOAA/National Centers for Environmental Prediction [NCEP]) compared outgoing LW fields over tropical oceans from NCEP reanalyses, Atmospheric Model Intercomparison Project (AMIP II) runs with corresponding fields from ERBE, CERES ERBE-like product, and AVHRR. He described recent changes in the NCEP reanalysis. Time series of LW from these sources showed significant differences. None of the model results showed the significant increase of LW for 1998 as shown by CERES data relative to ERBE.

Educational Outreach

Lin Chambers (LaRC) reported that over 480 schools from all 50 states and over 35 countries are now participating in the Students' Cloud Observations On-Line (S'COOL) program.

EOS Aura (CHEM) Science Team Meeting

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



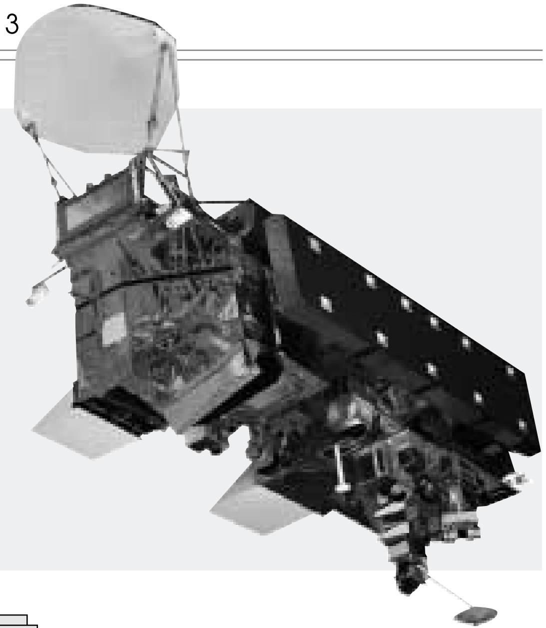
An EOS Aura Science Team meeting took place in Boulder CO on March 29-31, 2000. Mark Schoeberl (Project Scientist) opened the meeting. The first action was the final vote on the new name for the platform (which had been EOS CHEM until this meeting). Two finalists, "Aura" (from the Latin for air or breeze, akin to the Greek "aer" for air) and "Dobson" (Gordon Dobson [1889-1976] developed the first UV spectrophotometers to measure the ozone column), had been selected by NASA Headquarters from a large list of nominees. Aura was chosen over Dobson.

A review of the project status (Peg Luce, acting Project Manager and John Loiacono, instrument systems manager) followed the introduction of Phil DeCola as the new program scientist at NASA Headquarters. The impact of a six-month delay in launch (until June 2003) was discussed. The schedule for instrument delivery will be maintained to allow a longer time for observatory integration and testing. Principal Investigators reported on the status of the Aura Instruments: High Resolution Dynamics Limb Sounder (HIRDLS, John Barnett and John Gille); Microwave Limb Sounder (MLS, Joe Waters); Ozone Monitoring Instrument (OMI, Pieternel Levelt); and Tropospheric Emission Sounder (TES, Reinhard Beer).

A challenge to the entire science team and an important theme of this meeting was the development of the Aura validation plan. This plan must address the requirements for the validation of each instrument, termed here the core validation. The team is attempting to develop validation campaigns that will meet these core requirements but that are also focussed towards science questions and hypotheses. The team is attempting to identify hypotheses that can be addressed more fully by combining the advantages of a campaign utilizing the capability of aircraft and balloon platforms (e.g., spatial resolution, accuracy, speciation) with the advantages of satellite observations (global observations for long time periods). This process was begun with a meeting in August 1999 in Snowmass, CO, with participation by scientists associated with the Aura platform and also scientists associated with aircraft/balloon campaigns and measurements. The goal of that meeting was the development of white papers that will provide the scientific rationale for campaigns. These campaigns will be planned to begin no sooner than nine months after the planned launch; the long lead-time is required for commitment of the resources such as aircraft. Progress since the Snowmass meeting was reported in four areas: aerosols and polar stratospheric clouds (A. Tabazadeh); ozone trends (R. Salawitch); water vapor and climate (R. Newell and A. Tuck); and global tropospheric air quality (D. Jacob). Synthesis of campaign definition with the core validation requirements will take place over the next six months.

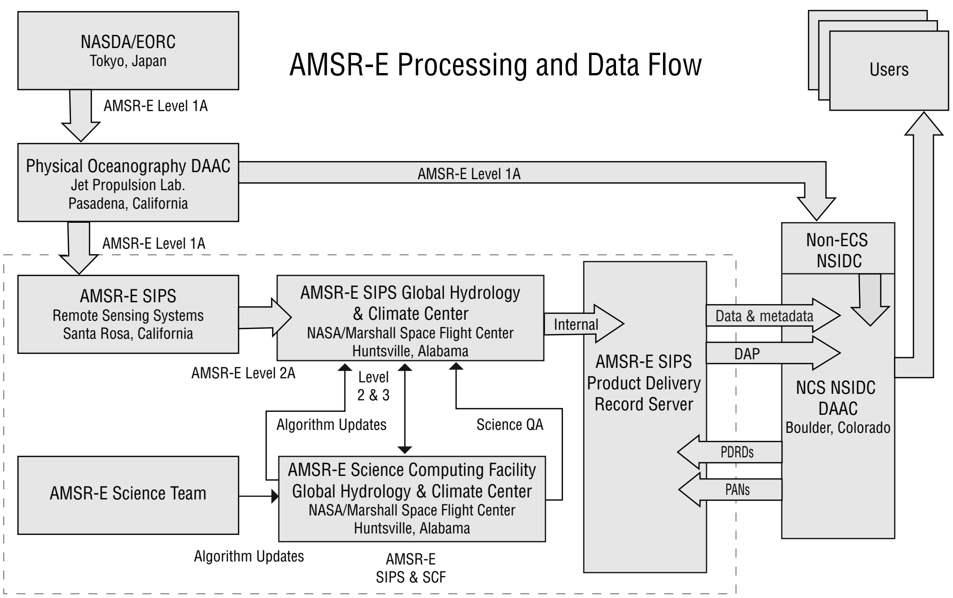
In addition to the Validation working group, working group meetings were held in the following areas: Algorithm (N. Livesey); Education and Outreach (E. Hilsenrath); Data Systems (S. Larson); and Aerosols (S. Massie). Current information about the activities of these working groups can be found on the Aura web site.

The scientific program consisted of 33 contributed presentations on varied subjects. Talks were presented related to retrieval and algorithm development for the Aura instruments, data assimilation, and also strategies for application of anticipated Aura data products. Some talks concerned analysis of observations from instruments on current platforms, including the Halogen Occultation Experiment (HALOE) and the MLS instruments on the Upper Atmosphere Research Satellite (UARS), and the Global Ozone Monitoring Experiment (GOME) on the European Space Agency's (ESA) second Earth Remote Sensing Satellite (ERS-2). The agenda from this meeting is found under the science working group on the Aura web site http://eos-aura.gsfc.nasa.gov/.



Aqua Advanced Microwave Scanning Radiometer (AMSR-E) Science Team Meeting

—E. Lobl (elena.lobl@msfc.nasa.gov), AMSR-E Science Team Coordinator, Earth System Science Laboratory, University of Alabama in Huntsville;
EOS Aqua AMSR-E homepage: wwwghcc.msfc.nasa.gov/AMSR



An AMSR-E Science Team meeting was held on March 14, 2000 at the Goddard Space Flight Center. This meeting preceded the second Algorithm Theoretical Basis Document (ATBD) and Validation Plan review. The main topics were software and AMSR-E Science Investigator-led Processing System (SIPS) status. Boris Petrenko made a presentation on his new rainfall algorithm. We closed the meeting with a short discussion of the AMSR-E brochure.

Dawn Conway (AMSR-E Software Integrator) presented the software status. All of the Engineering version software will be delivered by March 20, 2000. The launch version delivery is due to the Team Leader Scientific Computing Facility (TLSCF) by July 15, 2000. This software (the launch version) must produce HDF-EOS output files, with EOSDIS Core System (ECS) compliant metadata. It must also use the latest version of the Level 2A HDF-EOS data and read routine. The browse images will be HDF raster images, produced for each granule, with the software written at the TLSCF in IDL. The operational processing of these browse images as well as the standard products will be done at the AMSR-E SIPS. The Earth Science Data Types (ESDTs) list and the granule level metadata need to be finalized by the end of March and sent to ECS. The G-polygons spatial domain container must be included in the granule level metadata to ensure spatial search capabilities by ECS. The Launch version software will include the product specific attributes (PSAs) necessary to define the best-fitting "ideal orbit" for each granule.

Michael Goodman (AMSR-E SIPS Project Manager) described the AMSR-E SIPS organization and the processing and data flow (see chart). Parts of the network to be used have been tested (between RSS and GHCC). The ESDIS Network office has been monitoring the networks between JPL-RSS-GHCC and will make recommendations on possible improvements. The Interface Confidence Tests (ICTs) are scheduled to begin in June 2000 and will exercise the various individual components. The System Confidence Tests (SCTs) will follow, testing the entire system. On the status of the inter-element operations preparedness, Mr. Goodman reported the following:

NASDA - JPL: end-to-end test during summer 2000, trans-Pacific link being installed and tested

JPL - RSS: initial stages of Ops agreement, link operational

RSS - GHCC: network, data transfers and algorithms requirements well understood

GHCC - NSIDC: network and data transfers well understood, transfer protocols and Ops agreement being worked.

Quality assessment will be implemented through the use of automated algorithm specific checking of input parameters and setting quality flags in the data sets. The AMSR-E SIPS will provide short-term online access to Level 2A, 2B and 3 data sets for the AMSR-E science team members through a password protected web site. Once the “short term” period has expired, data will be available only at the NSIDC Distributed Active Archive Center (DAAC). All other users of the data must obtain the data from the NSIDC DAAC. Data will be transferred to NSIDC for archiving on a continuous basis.

Boris Petrenko (AMSR-E Science Team leader support) reported on a new rainfall algorithm that treats a horizontally inhomogeneous atmosphere as a combination of homogeneous domains. The off-line part of the algorithm involves selection of a minimum amount of “basis” hydrometeor profiles, allowing linear approximation of measured antenna temperature vectors, and adjustment of “basis” profiles to provide the best retrieval of all the profiles within a 3D cloud simulation. The on-line procedure includes determination of beamfilling coefficients and retrieving a footprint-averaged hydrometeor profile as a linear combination of “basis” ones.

Finally, Elena Lobl (Team coordinator) asked the team members to review the write-up for the AMSR-E brochure and provide any images/pictures that would be appropriate for the brochure.

High Resolution Dynamics Limb Sounder (HIRDLS) Calibration Review at Oxford, U.K.

— James J. Butler, (butler@ltpmail.gsfc.nasa.gov), NASA Goddard Space Flight Center, Code 920.1, Greenbelt, MD 20771

HIRDLS Calibration Review Attendees. Standing (left to right): Tom Parr, Jim Craft, Brian Johnson, Carol Johnson, Chris Palmer, Steve Richard, Wayne Rudolf, John Gille, John Barnett, Neil Martin, Daniel Peters, Soji Oduleye, Francesco Lama, Karim Djotni. Kneeling (left to right): Bob Watkins, Joanne Loh, Eric Johnson, Joe Rice, Jim Butler, Hima Nandi, Chris Hepplewhite, John Whitney, Ernie Hilsenrath.

A review of the calibration of the High Resolution Dynamics Limb Sounder (HIRDLS) was held April 5 and 6 in the Atmospheric, Oceanic, and Planetary Physics building at Oxford University in the United Kingdom (U.K.). The formal review panel included Jim Butler, NASA Goddard Space Flight Center (GSFC) (review chair and EOS Calibration Scientist), Ernest Hilsenrath, NASA GSFC (EOS Aura Deputy Project Scientist), Carol Johnson, National Institute of Science and Technology (NIST), and Joe Rice (NIST). The objective of the review was to examine the calibration approaches for the HIRDLS instrument which will be conducted at Lockheed Martin Space Systems Corporation (LMSSC) in Palo Alto, California, at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, and at Oxford University. Information on both the pre-launch and on-orbit calibration of HIRDLS was presented during the course of the review.

April 5 Presentations

John Barnett, from Oxford University and the HIRDLS principal investigator in the U.K., began the review by welcoming the attendees. **Jim Butler** followed Barnett and stated that the HIRDLS calibration review should involve the direct participation of not only the review panel but all attendees. Butler also encouraged the attendees to inquire on specific aspects of the HIRDLS calibration and to offer ideas on alternative calibration approaches.

John Barnett began the formal HIRDLS presentations by outlining the set of overarching scientific themes for the HIRDLS instrument. These include monitoring the recovery of ozone in the stratosphere, monitoring the natural dynamical and chemical variability of the stratosphere as a function of time and space, examining long term climate change with an emphasis on studies of global warming, and monitoring air quality in the upper troposphere. Based on those themes, Barnett presented a number of specific examples of intriguing yet outstanding scientific questions concerning the Earth's atmosphere which data from the HIRDLS instrument will be used to elucidate. With respect to stratospheric ozone and chlorine, Barnett pointed out that stratospheric chlorine levels are predicted to peak just before the EOS Aura mission. This places HIRDLS in a unique position to examine changes in ozone concentration with an anticipated decline in chlorine. Barnett concluded his presentation with a description of the major HIRDLS science emphases and a table of the science-derived instrument measurement requirements.

John Gille, from the University of Colorado and NCAR and the HIRDLS principal investigator in the United States (U.S.), presented a brief review of the HIRDLS limb measurement technique and the rationale for several of the driving measurement requirements. The HIRDLS instrument will measure infrared radiance emitted by the Earth's atmosphere at the limb in 21 spectral bands. Because the measurements are made as a function of altitude, errors in the line-of-site pointing knowledge of the HIRDLS instrument will introduce random errors in the HIRDLS radiance measurements. The center wavelengths and bandwidths of the 21 HIRDLS channels were carefully chosen relative to known atmospheric molecular absorption bands. Gille identified the critical measurement parameters for the HIRDLS instrument based on the fundamental instrument measurement equation and described the basic steps involved in the retrieval of temperature profiles and molecular mixing ratios. This necessarily led to the identification of the instrument parameters that must be calibrated. These include the gain, the spectral response function, the field of view function, and the measurement tangent height. The gain will be determined on-orbit; however, its traceability to international standards and anticipated non-linearities will be determined prelaunch. He concluded his presentation with a detailed list of the fundamental instrument radiometric and pointing requirements necessary for HIRDLS to meet its science goals.

John Whitney of Oxford University presented a detailed description of the HIRDLS instrument with emphasis on calibration-related design drivers and design features. Whitney began by identifying the instrument related parameters in the HIRDLS measurement equation which either affect or are affected by calibration. With respect to radiometric performance, the HIRDLS optical system is not cryogenically cooled while the final filter/dectector combinations are cooled. In addition, the position of the chopper in the instrument dictates that several mirrors will be detected as unchopped sources. Therefore, in order to meet its radiometric requirements, extensive thermal analyses, design, and monitoring have been performed and implemented in the HIRDLS instrument to ensure on-orbit radiometric stability. The on-orbit radiometric calibration of the HIRDLS instrument will be continuously assessed using views of its on-board blackbody and deep space. While the thermal/vacuum chamber at Oxford will permit limited measurements of the HIRDLS radiometric response versus the azimuthal angle of the scan mirror, a larger chamber at Lockheed Martin equipped with a turntable will be employed for these measurements. The spectral response function for the 21 HIRDLS bands will be measured prelaunch and will be assumed not to change on-orbit. HIRDLS employs conjugate pairs of filters to suppress spectral out-of-band leaks to the 10^{-8} level. These filters coupled with the intrinsic transmissive properties of the germanium and zinc selenide optics and the Hg/Cd/Te material response will provide effective out-of-band rejection. Stray light suppression in the HIRDLS instrument has been investigated at Lockheed Martin and at Oxford and will be determined primarily on-orbit using a pitch maneuver of the Aura platform. Ghost reflections between the HIRDLS detectors are anticipated not to be a problem based on modelling, testing, plus the use of anti-reflection coated optics, detectors, and filters carefully positioned on the optical bench and focal plane assemblies. Field-of-view mapping of the HIRDLS detectors will be performed using a fine measurement pixel provided by a monochromatic, collimated source. By using this source to illuminate single detectors, the presence of electronic and optical cross-talk between detectors can be directly determined. For HIRDLS, the instrument line of site (ILOS) pointing knowledge requirement is challenging. The ILOS will be determined on-orbit using position information from the Aura platform and data from the gyroscope assembly attached to the HIRDLS optical bench assembly.

Chris Palmer of Oxford University outlined the overall calibration approach for the HIRDLS instrument. Using a model incorporating the basic radiometric measurement equation and an equation for calculated filtered radiance, Palmer provided an overview of the fundamental spectral and spatial HIRDLS calibration quantities. Palmer also identified the location of the HIRDLS top level calibration requirements and quantities in the HIRDLS Instrument Requirements Document (IRD).

Bob Wells of Oxford University presented information on the current version of the HIRDLS Level 1 Algorithm Theoretical Basis Document (ATBD) titled, "Calibration and Geolocation of HIRDLS Radiances." Wells outlined the history of changes to the original document largely resulting from the ATBD review held in May 1999 at GSFC. The current versions of the algorithms for the calculation of radiances, error estimation, and tangent point location were presented.

Following lunch, **Chris Palmer** continued his series of presentations with an overview of the HIRDLS in-flight calibration. Palmer, starting from the basic equation linking telemetry counts with spectral radiance, derived the calibration algorithm equation incorporating linearized channel counts, virtual space and blackbody views, and the on-board blackbody radiance. The uncertainties in each quantity of the calibration algorithm were discussed and budget plots of calculated radiometric uncertainty versus the IRD requirements for HIRDLS channels 5 and 20 were presented. Palmer also presented modeled results of the predicted polarization response of the HIRDLS instrument. A full analysis of polarization effects in HIRDLS will be performed at Oxford University upon receipt of the HIRDLS engineering and flight models.

Palmer transitioned to the pre-launch timeframe and presented information on the pre-launch spectral, radiometric, and field-of view calibrations. In order to meet the IRD requirements for spectral calibration, the choice of monochromator and associated imaging optics is critical. A single monochromator with 4 gratings will be employed to enable spectral calibrations to be performed over all bands. Spectral measurements will include in-band spectral response measurements at a number of polarizer settings, out-of-band spectral response measurements, and uniformity of spectral response measurements. For radiometric calibration, HIRDLS will use two full-aperture illuminating blackbodies. One blackbody is fixed low temperature and simulates space view; the second blackbody has a variable temperature and simulates atmospheric views. A direct measurement of non-linearity is planned to be performed at Oxford in which a variable fraction of the viewed area of the blackbody will be obscured using cold baffles. The deployment of the NIST/EOS Thermal infrared Transfer Radiometer (TXR) at Oxford to measure the radiance of the variable temperature blackbody and to directly validate the radiances emitted from the blackbody in the non-linearity test was discussed and was agreed to be an idea to be pursued. HIRDLS field-of-view calibrations will be performed by generating a two dimensional field of view map of the HIRDLS focal plane at two optical bench temperatures.

April 6 Presentations

The second day of the calibration review began with **Bob Watkins** of Oxford University presenting information on the radiometric test equipment which will be used in the HIRDLS Test and Calibration Facility (T&CF). An impressive amount of work has been performed on the T&CF. The T&CF is an ultra-low vibration facility to enable testing and calibration of HIRDLS pointing. The cleanliness requirements for the facility are better than class 10,000 with a internal clean zone at class 10. The HIRDLS thermal vacuum chamber, which is located in the facility, will be equipped with internal shrouds that can be operated at different temperatures to simulate on-orbit thermal effects due to Earthshine and other orbital transients. The chamber size limits the number of azimuthal positions of the scan mirror for radiometric calibrations to two. All other azimuthal angles will be checked at Lockheed Martin in their larger chamber. The designs for the instrumentation used to perform the HIRDLS calibration and characterization are being finalized. Test equipment for performing precision field-of-view, spectral response, and end-to-end radiometric calibrations must operate under a range of thermal/vacuum conditions. HIRDLS spectral calibrations will be performed using a purpose-built, collimated, monochromatic source. HIRDLS radiometric calibration will be performed using two, large aperture blackbodies. These blackbodies will be 25.6 cm in diameter with interior surfaces painted with Nextel 811-21 diffuse black paint. In support of these calibrations, the NIST/EOS TXR would be used to measure the radiance from the variable temperature blackbody and would be operated in the thermal vacuum chamber at the position of the HIRDLS scan mirror. This would radiometrically validate the output of the blackbody as predicted from calculations by Oxford. The HIRDLS engineering model is scheduled to arrive at Oxford in November/December 2000 and the flight model is scheduled to arrive in July 2001.

Chris Palmer presented information on the HIRDLS detectors. Palmer stated that as the fine measurement pixel is moved across the HIRDLS focal plane, the fine measurement pixel rotates or "clocks" with respect to the detector orientation. It is believed that this will pose no problem in tests with the fine measurement pixel. In the HIRDLS engineering model, a test for cross-talk was performed in which individual channels were illuminated while other non-illuminated channels were monitored. This test verified that, in the case of the engineering model, cross-talk is not a problem. Oxford is currently working on a good technique to perform spatial uniformity mapping on their Hg/Cd/Te detectors. Finally, test results on the HIRDLS instrument will be published in the literature.

John Whitney provided several additional details on the test equipment, the collimated monochromatic source, and the calibration blackbody source. The collimated monochromatic source will be characterized for polarization. At the time of the calibration review, more than 50% of the design drawings were complete for this source. It is believed that the monochromatic source will provide enough signal for calibration purposes even at the longest HIRDLS wavelengths. If signal to noise is an issue, the integration time can be increased in the acquisition of calibration data using the monochromatic source. The issue of the flatness of the spectral responsivity of the HIRDLS detectors needs to be examined and addressed.

Special inflight tests and spacecraft maneuvers in support of HIRDLS on-orbit calibration and characterization were outlined by **Chris Palmer**. HIRDLS has requested that a 5 degree pitch down of the Aura spacecraft be performed at an early stage of the mission and then at periodic but infrequent occasions. This maneuver will enable all the HIRDLS detectors to view cold space, several degrees away from the warm Earth, to verify the stray light model. HIRDLS also would like to vary the temperature of the inflight calibration subsystem, which includes the calibration mirror, M6, and on-board blackbody. This would enable a check of the emissivity of M6 and the linearity of all the HIRDLS channels.

Immediately prior to lunch, the meeting participants toured the HIRDLS T&CF. Following lunch, **Bob Watkins** provided additional details on the HIRDLS on-board blackbody calibration source. This blackbody is designed to meet the challenging task of measuring absolute sensor drift to better than 5mK per year. The AC resistance bridge design in the source electronics may be the first time such a design has been incorporated in a satellite instrument. The blackbody for the EOS Terra Measurements Of Pollution in the Troposphere (MOPITT) instrument shares a design heritage from the blackbody which will be flown on HIRDLS.

Daniel Peters of Oxford University provided additional details on the HIRDLS on-orbit blackbody. This source will be used to provide HIRDLS a source of known, on-orbit radiance. The blackbody is a cavity design and uses Platinum Resistance Thermometers (PRTs) to determine temperature. The temperature of the blackbody is controllable using heaters. The blackbody must meet a total uncertainty budget of 70mK. To meet this challenging specification, the PRTs have been tested repeatedly over a temperature range from approximately 149 degrees C to –196 degrees C. The actual selection of temperature sensors was performed using a triple point cell. In the extensive testing of the on-board blackbody temperature sensors, a hysteresis was detected in going from low to high and high to low temperatures. Since the magnitude of this hysteresis is on the order of the sensor drift, additional work will be performed to decrease the hysteresis. In addition, inelastic deformation has been recognized as a cause of long term drift. In order to decrease this drift, HIRDLS has adopted Rosemount PRTs with silicon mandrels instead of aluminum mandrels. In the testing of the PRTs, the triple point cell is used to assess stability; and the actual calibration of the PRTs is performed using a standard thermocouple.

Information on the calibration of the on-board HIRDLS gyroscope subsystem was presented by **Soji Oduleye** of Oxford University. The gyroscope subsystem is designed to measure roll and pitch attitudes to high accuracy and to enable HIRDLS pointing knowledge to be accurately determined. Lockheed Martin will receive and install the subsystem onto the HIRDLS optical bench assembly, and Oxford will process all test data received. A calibration plan for the gyroscope subassembly was being formulated at the time of the calibration review.

Chris Hepplewhite of Oxford University presented the HIRDLS calibration schedule. Currently, Oxford University is in the process of preparing their facility and instrumentation for the receipt of the HIRDLS engineering model in the November/December 2000 timeframe. Oxford plans to formulate and finalize all instrument calibration plans and approaches in advance of the engineering model delivery. The HIRDLS engineering model is a complete instrument and will provide a valuable testbed for the subsequent flight model calibrations. There will be approximately 7 to 8 months from the time the engineering model arrives at Oxford to the time the flight model arrives. The flight model will be calibrated over a 4.5 month timeframe starting in the third week of August 2001. It is anticipated that one compact disc's worth of data will be produced per day from the calibration and characterization of the engineering and flight models at Oxford. University of Colorado, NCAR, and Lockheed Martin employees will be at Oxford during the time of the engineering model calibrations. There numbers will be increased during the time of the flight model calibrations. Oxford personnel will be stationed at Lockheed Martin in advance of shipping the engineering and flight models to Oxford. Delivery of flight software will occur in December 2001, with a planned update 6 months later.

The final presentation was made by **Eric Johnson** of Lockheed Martin. Johnson outlined the radiometric characterization and verification tests which will be performed on both the engineering and flight models at Lockheed Martin at the time of integration and test. Johnson also provided detailed information on the line-of-sight calibration and tests which are performed throughout the HIRDLS program. Johnson acknowledged that the boresight knowledge requirements for the HIRDLS instrument are very challenging.

The review concluded with **John Barnett** thanking the members of the review panel and members of the HIRDLS science and engineering teams for attending.

The Conical Microwave Imager Sounder

— Mark Flaming (mflaming@ipo.noaa.gov), Instrument Manager, National Polar-orbiting Operational Environmental Satellite System Integrated Program Office

Background of the NPOESS Program

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is a program currently in development for the purpose of providing global environmental measurements for use by the National Weather Service and other civil agencies, the Department of Defense (DoD), and the scientific research community. NPOESS will replace the Polar-orbiting Operational Environmental Satellite (POES) constellation currently operated by the National Oceanic and Atmospheric Administration (NOAA) and the DoD's Defense Meteorological Satellite Support Program (DMSP), a constellation of satellites which are also in polar orbit performing operational environmental measurements. International agreements are also pending with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) to incorporate and consolidate portions of that program with NPOESS. Managing the development of NPOESS is the Integrated Program Office (IPO) located in Silver Spring, Maryland. The IPO is jointly staffed by personnel from NASA, NOAA, and DoD. Briefly stated, the IPO's charter is to develop and field a total system that includes the space segment, the ground data processing segment, and the data distribution segment. The data products provided will include meteorological, surface (ground and oceanographic), and solar environmental data. The NPOESS System will process the raw data into Environmental Data Records (EDRs), and make the information available to users world wide. The first NPOESS satellite is projected to be launched in 2008. The program will include replenishment satellites, and will provide measurements for at least a ten-year period. A subset of three NPOESS sensors is planned for launch in 2005 as part of the NPOESS Prepatory Project (NPP). NASA's primary role at the IPO is to have lead agency responsibility to support the IPO in facilitating the development and insertion of new cost-effective and enabling technologies.

Five of the NPOESS critical sensors are currently in development. These five sensors are the Ozone Mapping and Profiler Suite (OMPS), the Cross Track Infrared Sounder (CrIS), the Global Positioning System Occultation Sensor (GPSOS), the Visible/Infrared Imager Radiometer Suite (VIIRS) and the Conical Microwave Imager Sounder (CMIS). A more complete description of the NPOESS Program, including its critical instruments and schedules, may be found at the NPOESS web site, URL at NPOESSLIB. IPO. NOAA.GOV. This article will briefly address the development of the CMIS sensor.

Conical Microwave Imager Sounder (CMIS) Environmental Measurements
CMIS is a passive microwave radiometer, an instrument that measures microwave emission from the Earth's atmosphere and surface. Through the use of appropriate measurement frequencies, polarized microwave receivers, and retrieval algorithms, various meteorological, oceanographic, and surface conditions can be inferred from these microwave emissions. After the raw data has been processed, the retrieved information is referred to as Environmental Data Records (EDRs). The EDRs measured by CMIS are extensive, and include the following:

- Atmospheric Vertical Moisture Profile
- Atmospheric Vertical Temperature Profile
- Imagery
- Sea Surface Temperature
- Sea Surface Winds (Speed and Direction)
- Soil Moisture
- Precipitable Water
- Precipitation (Type/Rate)
- Pressure Profile
- Total Water Content
- Cloud Base Height
- Cloud Ice Water Path
- Cloud Liquid Water
- Snow Cover/Depth
- Fresh Water Ice
- Ice Surface Temperature
- Sea Ice Age and Sea Ice Edge Motion
- Surface Wind Stress
- Land Surface Temperature
- Vegetation/Surface Type

These EDRs will be collected on a global basis approximately every six hours when the complete constellation of satellites is in place. These satellites will have nodal crossing times of 0530, 0930, and 1330, and will have CMIS on a satellite in each orbit. The complete attributes for each EDR are specified in the CMIS Sensor Requirements Document (SRD); this document is also accessible at the NPOESS web site identified above. Listed below, as an example, are the reporting requirements for the Atmospheric Vertical Moisture Profile EDR. The Threshold values represent the minimum performance required, while the Objective values represent the level of performance established by the IPO as goals for the sensor developer to attempt to achieve. The TBRs (To Be Reviewed) represent values subject to review during the program's development, and the TBDs (To Be Determined) represent values which will be defined during the program's development process.

Atmospheric Vertical Moisture Profile

An atmospheric vertical moisture profile is a set of estimates of the average mixing ratio in three-dimensional cells centered on specified points along a local vertical. The mixing ratio of a sample of air is the ratio of the mass of water vapor in the sample to the mass of dry air in the sample (table below).

	Thresholds	Objectives
a. Horizontal Cell Size	1.5 km	2 km
b. Horizontal Reporting Interval	(TBD)	(TBD)
c. Vertical Cell Size	2 km	2 km
d. Vertical Reporting Interval		
1. surface to 850 mb	20 mb	5 mb
2. 850 mb to 100 mb	50 mb	15 mb
e. Horizontal Coverage	Globe	Globe
f. Vertical Coverage	Surface to 100 mb	Surface to 100 mb
g. Measurement Range	0 - 30 g/kg	0 - 30 g/km
h. Measurement Uncertainty (expressed as a percent of average mixing ratio in 2 km layers)		
Clear		
1. surface to 600 mb	20% or 0.2g/kg (TBR)	10%
2. 600 mb to 300 mb	35% or 0.1g/kg (TBR)	10%
3. 300 mb to 100 mb	35% or 0.1g/kg (TBR)	10%
Cloudy (TBR)		
4. surface to 600 mb	20% or 0.2g/kg (TBR)	10%
5. 600 mb to 300 mb	40% or 0.1g/kg	10%
6. 300 mb to 100 mb	40% or 0.1g/kg (TBR)	10%
i. Mapping Uncertainty	5 km	1km
j. Swath Width	1700 km (TBR)	(TBD)

Acquisition Strategy

The acquisition of CMIS (as with the other four critical NPOESS sensors identified previously) is considered to involve substantial development and schedule risk. In order to achieve optimum performance, and to ensure delivery within the requirements for the NPOESS schedule, an early start for the Concept Development and Risk Mitigation Phase has been initiated. This phase started with the release to industry of a Request for Proposal in April 1997, and the award of two competitive development contracts in July 1997. Ball Aerospace and Technologies Corporation, Boulder Colorado, and Hughes Space and Communications Company, El Segundo, California were the successful bidders. The first phase will conclude with a Preliminary Design Review (PDR) for each contractor in the spring of 2001. Following PDR one contractor will be selected for completion of engineering development, and production of up to seven flight units. Delivery of the first flight unit is scheduled to take place in late 2005. This delivery date will provide an adequate opportunity for the integration and test of CMIS and the other sensors on the first NPOESS spacecraft prior to its launch in 2008.

The acquisition of CMIS is centered upon a performance-based specification (the CMIS Sensor Requirements Document) which requires the contractor to develop a system able to provide the 20 EDRs listed previously. The development effort requires each contractor to assess the scientific phenomenology associated with microwave retrievals for the areas of interest, determine the performance capabilities of the retrieval algorithms, specify the performance which the instrument must achieve, and flow those performance requirements into the design of the sensor. Specific factors that influence the design of the sensor include:

- The large number and variety of EDRs (which influence the number and selection of the microwave frequencies measured).
- The accuracy and precision with which the measurements must be made.
- Spatial resolution requirements.
- System operating lifetime requirement.
- Spacecraft accommodation constraints such as mass, power and data rate.
- Life cycle costs (LCC).

The design of CMIS will incorporate state-of-the-art technologies in order to achieve many of the more stressing performance requirements. Where advanced technologies are being considered, or where implementation of a design approach is considered to represent substantial risk, the contractor will build and test hardware prototypes to demonstrate the viability of its chosen approach.

The contractors developing CMIS are responsible for the delivery of a system that includes the retrieval algorithms as well as the instrument hardware. Advising the CMIS Instrument Manager on scientific topics and algorithm development is the Microwave Operational Algorithm Team (MOAT). The MOAT is a tri-agency (NASA, NOAA, DoD) group of research scientists which, collectively, has scientific expertise for each CMIS EDR and the associated retrieval algorithms. In addition to algorithm development, the MOAT provides advice regarding the detailed performance specifications of each EDR, and makes recommendations for those parameters requiring further review or specification (e.g. TBRs and TBDs). MOAT, thus, provides not only advice regarding system development, but also has the opportunity to provide input into the performance capabilities of the system.

Sensor Characteristics

A number of spaceborne microwave sensors have been developed for scientific research and operational meteorological purposes. Examples included in this list are the AMSU-A and AMSU-B series of instruments, the Special Sensor Microwave Imager (SSMI), the Special Sensor Microwave Imager Sounder (SSMIS), the TRMM Microwave Imager (TMI) and the Advanced Microwave Scanning Radiometer (AMSR). It should be noted that CMIS will incorporate into a conical scan system both a surface measurement and atmospheric sounding capability; earlier instrumentation frequently performed surface measurements with a conical scan system, and employed a cross-track scan system for atmospheric soundings. CMIS represents a continuation in the trend of microwave instruments that are more capable, but also more complex. As mentioned previously, the CMIS program is currently in competitive development, and thus the details of the specific design implementations cannot be discussed. However, some general characteristics may be inferred from requirements stated in the CMIS Sensor Requirements Document, microwave phenomenology, and characteristics of other microwave radiometers. In regard to physical size, the accommodation numbers specified in the CMIS SRD constrains the instrument with Not-To-Exceed (NTE) values of 275 kilograms for mass, 340 watts for power and 500 kilobits per second for data output; the spacecraft and launch vehicle place limitations on the maximum stowed dimension for a rigid antenna of approximately 2.5 meters diameter. In the table below some of the physical characteristics

Microwave Sensor Comparison

	SSM/I	TMI	SSMIS	AMSR-E	CMIS* Target / NTE
Antenna Diameter	.6 m	.6 m	.7 m	1.6 m	2.5 m / TBS
Number of Measurement Channels	7	9	24	12	35+ (Contractor Specified)
Mass	56 kg	62 kg	96 kg	324 kg	250 / 275
Power	45 w	50 w	135 w	350 w	225 / 340 w
Operational Design Life	3 yrs	3 yrs	5 yrs	6 yrs	7 yrs

* The CMIS SRD specifies Target and Not-to-Exceed (NTE) values for key spacecraft accommodation parameters. The number of measurement channels is determined by each CMIS vendor, with the value of 35+ channels intended to indicate the minimum number which may be able to satisfy requirements; the actual contractor implementations may vary substantially from this value.

of the conical scan sensors mentioned above are compared with CMIS.

The approaches used by other instruments for satisfying measurement requirements suggest similar design characteristics may be used by CMIS. Soil moisture and sea surface temperature are measured by AMSR with a 6.9 GHz channel; atmospheric vertical temperature profiles are measured by AMSU-A using a series of channels in the 50-to-60 GHz range. The SSMIS is a new instrument in terms of its development (its first flight is expected to take place in November 2000), and will measure atmospheric water vapor using 150 GHz and 183 GHz channels; similar channels are also being used by AMSU-B to make the same measurements. Although not used in operational instruments constructed to date, the phenomenology suggests that frequencies greater than 183 GHz may have an application, if the appropriate technology can be developed.

The measurement of ocean surface wind direction is a new requirement for space-borne passive microwave sensors. In the past, this measurement has been performed from space with an active instrument such as the NASA Scatterometer (NSCAT). The mass, power, and fields of view available on the NPOESS spacecraft, as well as cost, present significant challenges to the use of an active system. The passive microwave approach has successfully been demonstrated from aircraft, but no experience exists with the use of this technology from space. The passive approach uses polarimetric measurements of the microwave emissions from the ocean's which are then used to calculate the wind vector. NPOESS is participating in the WINDSAT/CORIOLIS Program, a development by the Naval Research Laboratory, which will serve as a technology demonstrator and risk- reduction effort for the NPOESS CMIS. WINDSAT will demonstrate the viability of using a space-borne platform to obtain the polarimetric measurements needed to calculate ocean wind speed and direction. This program has recently completed its Critical Design Review (CDR), and is now in the process of constructing a multi-channel, polarimetric receiver. This satellite, scheduled for launch in December 2001, involves the first use of a Rapid Development Spacecraft Office (RDSO) catalog bus for a non-NASA mission.

Thus, the measurements that CMIS must perform may span the frequency range from 6 GHz to 183 GHz, or more, and may employ polarimetry for the measurement of vector winds. The physical size of the instrument, the large number of measurement channels required for the 20 EDRs, the sensitivity required for the measurement channels, and a very long operating life (seven years), all suggest the development of an extremely complex instrument.

Kudos

Dr. Charles K. Gatebe, a member of the MODIS Team, and a former meteorologist and lecturer at the Institute of Nuclear Science of the University of Nairobi, was selected the winner of the Year 2000 World Meteorological Organization's (WMO) Young Scientist Award. This followed the presentation of his PhD. thesis titled "Characterization and transport of aerosols at a high altitude on Mount Kenya." This award was started by WMO to encourage young scientists to conduct research in the field of meteorology and related sciences. It is competed for by scientists from all the 185 member countries of WMO world-wide.

The selection and announcement of the winner was made during the 52nd Session of the Executive Council (EC) of WMO, which took place in Geneva, Switzerland from May 15 - 26, 2000. The Council is composed of 36 members, elected from among the Directors of Meteorological Services of the WMO membership, during the World Meteorological Congress held in May 1999.

The Earth Observer staff joins the EOS community in congratulating Dr. Gatebe on this outstanding achievement.

Calibration Workshop for the Total Irradiance Monitor (TIM) Instrument on the Earth Observing System's (EOS) Solar Radiation and Climate Experiment (SORCE)

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Introduction

A workshop on the characterization of the TIM instrument scheduled to fly on the EOS SORCE mission was held at the Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, CO, on May 3 and 4, 2000. Participants included representatives from LASP, NASA's Goddard Space Flight Center (GSFC), NASA's Jet Propulsion Laboratory (JPL), the National Institute of Standards and Technology (NIST), the Naval Research Laboratory (NRL), the Royal Meteorological Institute of Belgium, the Physikalisch-Meteorologisches Obseratorium Davos/World Radiation Center (PMOD/WRC), Columbia University, and Boulder Metric.

The goal of this workshop was to identify, examine, and discuss the most important issues in the characterization of the TIM instrument and, for each issue, obtain the expert recommendations of the workshop participants on how to proceed.

SORCE Background

Following brief self introductions by the meeting attendees, Gary Rottman, of LASP and the principle investigator for EOS SORCE, provided a TIM science overview. He began by outlining a short history of LASP and the evolution of the SORCE mission. The EOS SORCE mission is comprised of four instruments: the TIM, the Spectral Irradiance Monitor (SIM), the SOLar STellar Irradiance Comparison (SOLSTICE), and the Extreme ultraviolet Photometer System (XPS). The EOS SORCE mission is currently scheduled for launch July 30, 2002 on a Pegasus XL rocket. Data from all the instruments will be archived at the GSFC Distributed Active Archive Center (DAAC).

Rottman then presented a plot of the historical record of total solar irradiance measurements. In this plot, the 3000 ppm spread of the data was identified as probably being due to systematic errors between the instruments. With this historical total irradiance data record as a backdrop, the measurement accuracy and precision specifications for the TIM instrument were stated to be 100 ppm absolute accuracy, 10 ppm per year relative accuracy, and 20 ppm precision (i.e. relative uncertainty). LASP is building three TIM units: a flight unit, a witness unit, and a space shuttle hitchhiker unit.

May 3 Technical Presentations

The technical presentations began with George Lawrence of LASP providing a characterization overview of the TIM instrument. Lawrence stated that he hoped that the workshop would focus on specific testing issues of the TIM instrument rather than design issues. The prototype for the TIM instrument was completed in November 1998 and LASP is currently in the process of building flight units. Assuming the flight instrument will be assembled in the June/July 2000 timeframe, LASP will have approximately 9 months to perform several specific characterization and calibration activities before the projected April 2001 spacecraft integration date. Select calibration and characterization activities can be delayed past April 2001. The long term stability goal for the TIM instrument of 10 ppm/year will be achieved by radiation testing the TIM cones, storing the TIM flight instrument in a clean, inert argon atmosphere through launch, duty cycling the 4 TIM cones on-orbit, and maintaining at LASP an extensive system of witness apertures, standard ohm, standard volt, and standard rulings used to determine aperture area. Long term stability will also be determined through validation flights of the hitchhiker TIM on the shuttle and by careful maintenance and testing of the witness TIM at LASP. Early in his presentation, Lawrence provided a list of definitions and notations to be used throughout the workshop. Lawrence also outlined his strategy for producing the TIM uncertainty analysis. In this analysis a parametrized model with uncertainties is constructed. Monte Carlo numerical calculations are used to propagate 10^4 random configurations through that model. Lawrence concluded his presentation by pointing out major design features of the TIM instrument cones, heat sink, baffles, and electronics.

Greg Kopp of LASP described the possible operational modes of the TIM instrument. The actual operational modes of the instrument will be defined over the next two years. The TIM instrument employs four cones, designated A through D, which are operated at different duty cycles to enable the determination of on-orbit degradation. Having four identical cones, any one of which can be the primary observing cone, provides operational flexibility. Currently, the duty cycles for the 4 TIM cones are 98.9% for cone A, 1% for cone B, 0.1% for cone C, and 0% for cone D, which provides a thermal reference and redundancy. During the workshop, the desire for performing a single exposure of cone D to solar irradiance early in the mission was discussed and endorsed by a majority of the attendees. In addition, there was some discussion on the exact duty cycles for cones B and C. The three-axis stabilized spacecraft will enable cruciform scans of the Sun to be performed to determine pointing corrections. In addition, field of view maps and scans of dark space will be performed on-orbit.

A number of possible on-orbit degradation mechanisms were identified and discussed by the workshop participants. These included contamination by space dust, attack by atomic oxygen, micrometeorite strikes, and general molecular contamination. The workshop attendees generally agreed that little could be done to prevent these degradation mechanisms or to predict the magnitude of their effects on the TIM instrument measurements. LASP requested that the attendees provide a list of degradation mechanisms, available references on those mechanisms, and ideas for ancillary measurements which could be made to quantify the anticipated degrees of degradation.

Kopp followed the degradation discussion with an overview of the possible intra- and inter-instrument comparisons using the TIM instruments. A key to making total solar irradiance comparisons with other instruments will be the detection of long term changes between the three copies of the TIM instrument. Specifically, the need to discern changes in the hitchhiker TIM or the witness TIM was discussed. The hitchhiker TIM will be deployed on the shuttle and will be used in measurement comparisons with the on-orbit SORCE instrument and with other total solar irradiance instruments. The current LASP strategy is to assume the witness TIM is the standard instrument. LASP is examining the possible use of the High Accuracy Cryogenic Radiometer (HACR) at NIST or trap detectors to detect changes in the witness TIM. The challenge to LASP is to validate that the hitchhiker TIM is measuring identically on-orbit as to how it measures both pre-launch and post-launch.

George Lawrence described the phase detection technique used in the TIM instrument. This technique, new to solar irradiance measurements, enables the high accuracy goals of TIM. Lawrence outlined a number of advantages in using the phase or synchronous detection technique in TIM over the conventional time domain analysis technique. A number of specific issues concerning the phase detection technique were discussed. These included optimizing the frequency at which the feed forward value is updated and optimizing the number of cycles over which boxcar averaging is performed.

George Lawrence continued his series of presentations by describing the basic TIM measurement equation. Beginning from the signal flow diagram, the measurement equation was presented. This equation relates the various parameters of the TIM instrument to the retrieved total solar irradiance. The measurement techniques used to calibrate the various instrument parameters and associated uncertainties were presented. Discussions took place on the accuracy of the aperture area measurements performed at LASP and on qualifications to the uncertainty budget due to largely unquantifiable but real effects. These include contamination, magnetic field effects, atomic oxygen attack, micrometeorite strikes, launch vibrational effects, electronic interference, and molecular contamination. The possibility of using the Sun to illuminate all the cones and thereby enable pre-launch comparison measurements between all cones was discussed. The problem of properly accounting for the solar aureole in such a measurement was identified as a possible source of pointing related uncertainty greater than 1000 ppm. It was recommended that LASP spend time with the spacecraft vendor well in advance of launch to thoroughly understand the Sun-pointing system which will be used on the EOS SORCE spacecraft.

Greg Kopp presented information on the TIM shutter waveform. Each cone on the TIM instrument will be equipped with its own independent shutter. The shutters will be made of aluminum with the sun-facing surface clear anodized for high visible reflectivity and the radiometer-facing surface gold plated for low infrared emissivity. Thermistors will be embedded in each shutter, and a photodiode will be used to validate shutter position. LASP has completed 6.1 million shutter cycles, equivalent to 3.2 times the projected TIM usage, at temperatures between –40 to 60 degrees C. A discussion was held on the use of double shutters to decrease the amplitude of the temperature swings between open and closed states, a calibration which will be obtained by observation of dark space. During these discussions it was pointed out that the rise time of the shutter waveform could change (i.e. become faster) on-orbit due to slow degassing processes. It was recommended that a movement model of the shutter mechanism be constructed and the model be used to predict shutter operation over a range of values for the shutter friction. Lastly, a feedback loop employing a detector would enable an important validation that the shutter is in a completely open and not partially open state. Measured shutter waveforms show a negligible (<1 ppm) effect on the TIM measurement.

May 4 Technical Presentations

George Lawrence began the second day of presentations with information on the TIM apertures. The aperture area uncertainty of 78 ppm is the largest component in the TIM measurement uncertainty budget. Thirty diamond-turned aluminum apertures have been fabricated for LASP by a private company. The current plan is to measure the area of the 30 apertures at LASP and compare those to measurements made at LASP on 3 NIST apertures used as standards. A discussion was held concerning whether the TIM instrument should fly NIST apertures or the ones which they procured from a private company. The procured apertures were fabricated from 6061 T6 aluminum. Electronmicrographs of the edge of those apertures showed burrs that were on the order of 1 wavelength in size. While copper NIST apertures have sharper edges, the group concurred that there were too many concerns with copper in space environments to fly the NIST apertures.

The measurement of aperture areas at NIST and at LASP was extensively discussed. NIST has the capability of measuring aperture area using two techniques. The first technique is an optical flux measurement relative to an aperture of known area. The second technique is an absolute measurement of the geometrical area of an aperture. In their aperture measurements, LASP uses a combination camera plus CCD detector which measures the transmission integral or function through the aperture. The advantage of the LASP measurement is that the optical transmission function of the TIM aperture, including diffraction and solar incidence angles, is determined. A disadvantage of the LASP system is the insensitivity of the CCD detector beyond 1 m. The LASP camera/CCD system is calibrated using Ronchi rulings. Recommendations from the workshop participants included a request that LASP examine why the CCD could not be placed after the aperture with no intervening optics in a position identical to that of the cones. Improvements to the operation of the LASP aperture area measurement system were also discussed. For example, the 1% ghost reflection off the CCD window could be decreased and/or eliminated by using an AntiReflection (AR) coated window on the CCD, or a CCD with no window. The LASP system currently uses AR coated achromats which could be the source of 0.1% viewing glare. By converting the achromats to conventional lenses this effect might be eliminated. LASP requested NIST assistance in understanding calculated diffraction effects from the aperture and intervening baffles. An important point made during these discussions was that historical differences between total solar irradiance measurements could be due to a combination of errors in aperture area measurements and incorrect or neglected diffraction corrections. The possibility of an EOS round-robin on aperture area measurements was favorably discussed by the workshop participants.

Greg Kopp followed the aperture discussions with a presentation on the absorption of the TIM cones. The interiors of the TIM cones are plated with NiP black, while the baffles in front of the cones are treated with Epner black. The current assumption in the operation of any given cone is that photons which leave a cone do not re-enter the cone. Light scattering calculations were performed on the cones by Breault Research Organization (BRO) Incorporated of Tucson, Arizona. Input to the BRO scatter model included total integrated scattering (TIS) and bidirectional reflectance distribution function (BRDF) measurements performed by Schmitt Measurement Systems of Portland, Oregon.

Kopp described LASP laboratory equipment used to directly measure the reflectance from the interior of the cones. The current setup employs a two-dimensional photodiode array positioned to face the interior of the test cone. In the center of the array is a hole which a laser beam passes through and illuminates the cone. Since a photodiode array is currently used, the wavelength range of these measurements have been limited to below 1 m. The technical challenge in this setup will be to procure mid-wave infrared and long-wave infrared detectors with large active areas. The possible use of a pyroelectric detector was discussed for this application.

Detector uniformity and sensitivity will be measured at LASP for one method of reflectance measurement normalizaton. It was pointed out that the NIST Spectral Irradiance and Radiance Calibrations with Uniform Sources (SIRCUS) facility has the current capability of measuring detector sensitivity. In another method of LASP reflectance measurement normalization, the cone reflectance is referenced to the reflectance of a Spectralon panel. In the LASP measurements, the Spectralon panel is illuminated at normal incidence and the photodiode detectors sample scattered light from the Spectralon over a range of angles around normal incidence. Given this illumination/scatter geometry, the use of the Spectralon directional hemispherical reflectance integrated over the used portion of the photodiode array instead of the bidirectional reflectance factor (BRF) was questioned. Using the integrated BRF instead of the directional reflectance should produce a cone reflectance higher by perhaps 5 to 7%. Interestingly, a comparison of the LASP cone reflectance measurements using their detector map calibration method and their Spectralon calibration method reveals that the reflectances produced from the Spectralon method are lower by approximately that amount.

The LASP reflectance measurements will be performed at a number of discrete laser wavelengths. The possibility of using a NIST Fourier Transform InfraRed (FTIR) spectrometer for these measurements was discussed. The FTIR approach would enable the measurement of reflectance over a continuous wavelength range into the infrared. A potential obstacle to the FTIR approach would be insufficient signal-to-noise from the cones.

LASP plans to maintain a record of cone reflectance measurements over time in an effort to monitor changes. The reflectance of the flight cones will be monitored on-orbit to the 1 ppm level using a photodiode detector. The importance of periodic measurements of cone reflectance was illustrated in two specific instances. First, LASP discovered that the NiP black surface treatment increases in reflectance following ultrasonic cleaning in isopropyl alcohol. Because of this effect, the cones are no longer ultrasonically cleaned. In addition, an increased reflectance was detected following the soldering and cleaning of one particular cone. This increased reflectance was attributed to a lifting of the NiP black plating due to thinness in the initial NiP black plating. With respect to environmental testing, the cones have been vigorously vibrated but not acoustically tested. The requirement for acoustic testing of the cones was identified as an issue to be re-examined. Lastly, the effect of illuminating different areas of the cones was identified as an additional contributor to the overall reflectance measurement uncertainty of the TIM cones, requiring spatial reflectivity maps that LASP is acquiring.

George Lawrence presented information on optical/thermal equivalence in the TIM instrument. Equivalence is the amplitude and phase ratio of the thermal impedances or temperatures produced per power input from solar irradiance versus those from replacement heating. The need to determine the on-orbit variation in TIM equivalence as a function of instrument pointing was discussed. The ratio of the finite element analysis calculations for the situations of applying optical versus thermal power was identified as an item to be examined. Lastly, a power measurement versus an absolute cryogenic radiometer could constitute a good check of not only heater wire equivalence but also cone absorptance. By moving an intensity stabilized laser beam input across the cone, the cone responsivity could also be mapped.

George Lawrence presented information on the TIM servo and electronics. Lawrence explained the role of the servo in the measurement of the closed loop gain, identified and explained the TIM electronic system components and features, and outlined the features of the standard ohm and volt.

George Lawrence explained the origin of the dark signal in the TIM instrument. During space views, the baffles in the TIM instrument will modulate in temperature at the shutter frequency. However, this effect should be small due to the thickness of the baffles and the fact that this modulation will be out of phase with the shutter. The need for an optical model taking into account coupling with every component within the field of view of the cavity for all viewing modes was identified. In addition, modeling of the baffle temperature changes during all viewing modes should be performed.

The TIM calibration workshop concluded in the late afternoon after a list of suggestions to improve TIM calibrations and characterizations was compiled.

Report on SAFARI 2000 Outreach Activities, Intensive Field Campaign Planning Meeting, and Data Management Workshop

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Background – Aim of SAFARI 2000

The Southern African Regional Science Initiative - SAFARI 2000 - is an international science initiative aimed at developing a better understanding of the southern African earth-atmosphere-human system. The goal of SAFARI 2000 is to identify and understand the relationships between the physical, chemical, biological and anthropogenic processes that underlie the biogeophysical and biogeochemical systems of southern Africa. Particular emphasis is placed upon biogenic, pyrogenic and anthropogenic emissions, their transport and transformations in the atmosphere, their influence on regional climate and meteorology, their eventual deposition, and the effects of this deposition on ecosystems. To accomplish this, SAFARI 2000 participants will:

- integrate remote sensing, computational modeling, airborne sampling and ground-based studies;
- link the biological, physical and chemical components of the regional ecosystems by integrating them within the semi-closed atmospheric gyre persistent over the region; and
- combine the expertise and knowledge base of regional and international scientists.

The SAFARI 2000 vision is a 3-year ground-based and satellite data collection period, beginning in mid-1999 and ending in 2002, and periodic intensive field campaigns including enhanced airborne and ground observations during wet and dry seasons.

In preparation for the third intensive field campaign (IFC 3) of SAFARI 2000, a large number of North American, European and Southern African scientists converged upon southern Africa during March-April 2000. Numerous briefing, outreach and education activities, in support of NASA EOS and SAFARI 2000, took place before, during, and after the SAFARI 2000 Intensive Field Campaign Planning Meeting that was held April 3-6, 2000, in Pietersburg, South Africa and the 28th International Symposium on Remote Sensing of Environment held in Cape Town, South Africa March 27-31, 2000.

Outreach Activities

NASA EOS outreach activities in support of or affiliated with the SAFARI 2000 effort included thirteen presentations of the NASA EOS Electronic Theater in three different countries: Botswana, Zimbabwe, and South Africa. Michael King and Fritz Hasler, NASA Goddard Space Flight Center, and Bob Swap, University of Virginia, gave these presentations. The EOS Electronic Theater is an Imax-like large screen presentation of Earth science topics, satellite imagery, and data animations. These presentations were typically held in large auditoriums with up to 1000 attendees. The venues ranged from national conference venues, to historically disadvantaged universities, to town halls.

NASA EOS educational outreach was conducted by Jim Closs, Charlotte Griner, and Winnie Humberson, with presentations targeted mainly at high school educators. These presentations were similar to the EOS Electronic Theatre, but smaller in scale, and were held in Pretoria, Pietersburg, and Port Elizabeth, South Africa. EOS educational material was also distributed in concert with the overview presentations on the NASA EOS and SAFARI 2000 programs. Audiences reached during these talks included K-12 students, undergraduate and graduate students, academics, professionals and the general public. NASA and SAFARI 2000 representatives also gave numerous print, radio, and television interviews. NASA's Earth Science Enterprise also participated as an exhibitor at the 28th International Symposium on Remote Sensing of the Environment in Capetown. Attendees were provided ESE program documentation, and many educational posters, brochures, fact sheets, and lithographs.

SAFARI 2000 Dry Season Intensive Field Campaign Planning Meeting

The planning meeting held in Pietersburg, RSA, from April 3–6, 2000 focused on the logistics and operations plans for the August-September 2000 Intensive Field Campaign, SAFARI 2000 IFC 3. An effort was made to coordinate validation and science activities of the NASA ER-2 remote sensing aircraft with those of the four *in situ* aircraft: the University of Washington CV-580, the UK Met Office C-130, and the two South African Weather Bureau Aerocommander 690As. Three Terra instrument teams were represented – MISR, MODIS and MOPITT. In addition, the NASA EOS ground-based validation activity, SAVE (Southern African Validation of EOS) and its core tower sites were represented, as were regional science and validation activities. Approximately 65 people participated in the meeting, including scientists from the region (Botswana, Mozambique, Namibia, South Africa, Zimbabwe, and Zambia) and from elsewhere (United States, United Kingdom, and Canada). The key objectives of the meeting were to:

1) outline the logistics for the campaign in terms of airport facilities, communications, equipment shipping arrangements, etc.;
2) provide an overview of the overall SAFARI 2000 objectives and determine how airborne flight plans could be tailored to best suite these objectives;
3) ascertain developments with regard to ground-based activities, with the specific purpose of determining what activities will be undertaken (by whom) during the intensive field campaign;
4) collate information regarding the instruments to be aboard each of the aircraft, including the parameters to be measured and the types of data to be produced;
5) rehearse the mission planning procedure to be implemented during IFC 3, which included: (a) forecasting, presentation and interpretation of meteorological scenarios, and trajectory modeling outputs; (b) determination of satellite/sensor overpass times and swath widths; and (c) development of flight plans; and
6) establish the status of SAFARI 2000 data planning and put in place data management procedures for the campaign.

Therefore, the meeting focused on three main areas: descriptions of ground-based and airborne *in situ* and remote sensing activities during the IFC 3; presentation of and planning around a number of different meteorological and Terra overpass scenarios; and discussion of the SAFARI 2000 data management structure. Activities on Day 1 focused primarily on overviews and updates of SAFARI 2000 and NASA EOS in general and on specific plans for ground-based, airborne, satellite, and validation activities as part of IFC 3. A volume sector approach that integrates ground-based and airborne *in situ* and remote sensing observations with the scientific and validation investigations to achieve SAFARI 2000 objectives was presented (Figure 1). This volume approach took into account the nominal range of the research aircraft involved (Figure 2).

Much of the activity on the second and third days focused on the presentation of a number of weather briefing scenarios for the purposes of the IFC 3 flight planning. Meteorologists from Botswana, Zimbabwe and South Africa gave detailed presentations on the meteorology of the region. The South African Weather Bureau also

Figure 1

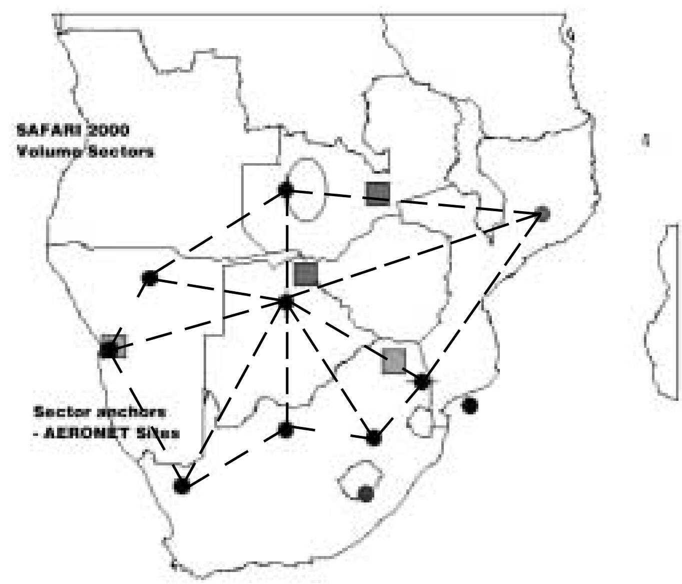
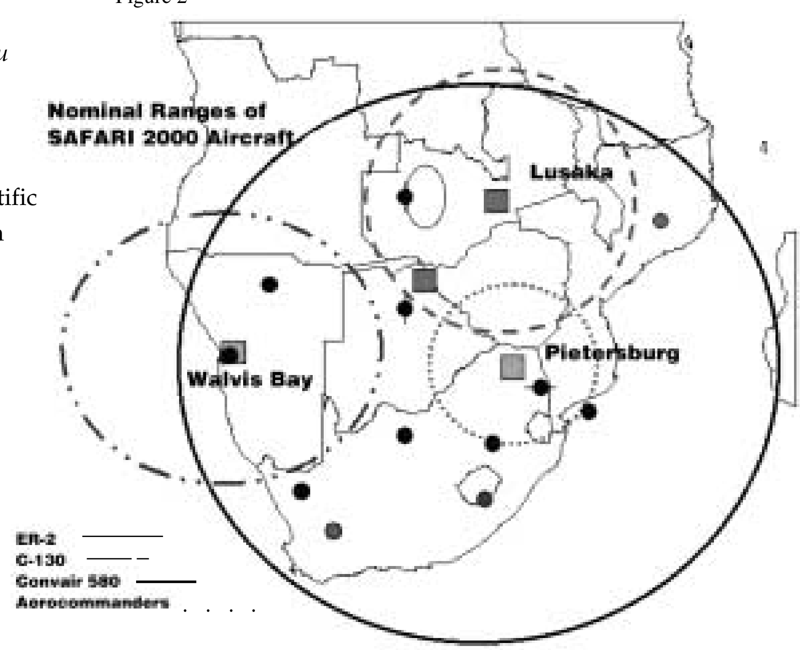


Figure 2



gave detailed, in-depth forecasts of typical scenarios for the purposes of flight planning. Scientists from the different airborne platforms participated in group discussions that focused on the planning of flight paths in response to the given meteorological and Terra overpass scenarios. Plenary discussion and debate followed with the end results being the creation of generalized flight paths for a given meteorological and satellite overpass condition.

Activities on the fourth day focused on operations logistics and data management. Operations logistics at the various tower sites and at the Pietersburg SAFARI 2000 IFC 3 Operations Control Center were presented and discussed during the first part of the day and the overall SAFARI 2000 data management structure afterwards. Bob Cook, Oak Ridge National Laboratory (ORNL) EOS DAAC, presented a strawman data management structure. Cook's presentation was based on discussions at last year's SAFARI 2000 Regional Implementation Workshop held in Gaborone, Botswana as well as discussions during the first several days of the Pietersburg meeting. It was concluded there were a number of outstanding issues and that a small Data Management workshop should be held within two months of the conclusion of the Pietersburg meeting.

Key Products from the IFC 3 Planning Meeting

1) Detailed meeting proceedings available on the web at: http://safari.gecp.virginia.edu/reports/Proc5June00.htm.
2) Outline for the IFC 3 Operations Handbook that is now being distributed for comment.
3) A set of agreed upon general, coordinated flight plans for IFC 3 that take into account the needs of ground-based and airborne *in situ* and remote sensing platforms and their validation and science requirements.
4) A strawman data management structure that subsequently was finalized at a Data Management Workshop hosted at the University of Virginia and NASA GSFC during the week of June 12-16, 2000.

ORNL, a NASA Earth Science Information Partner (ESIP) Type 2 and the University of Witwatersrand (WITS) in South Africa. A schematic of the SAFARI Data Management Structure is presented in Figure 3. GSFC's role will include creating CD-ROMs, procuring "tasked" imagery such as Landsat 7, and establishing data pipelines for sending EOS imagery to the newly-initiated SAFARI Regional Data Center at WITS. The plan was presented to Michael King, David Starr, and Henry Watermeyer, Head of IT at WITS. The PowerPoint version of this presentation is available on the web at mercury.ornl.gov/safari2k/other_links.htm

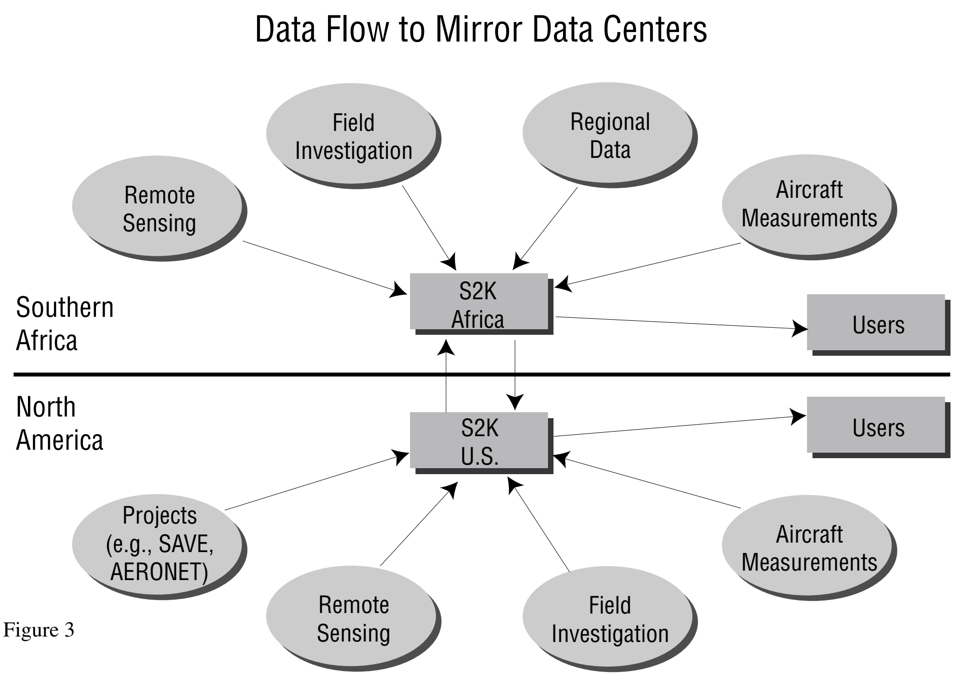


Figure 3

SAFARI 2000 Data Management Workshop

The SAFARI 2000 Data Management Group hosted Information Technology (IT) specialists from southern Africa during the week of June 12 at the University of Virginia (UVa), NASA Goddard Space Flight Center (GSFC), and the ORNL DAAC. Participants completed a plan for a distributed data sharing system, capitalizing on existing expertise at GSFC,

Participants in the workshop included Lance Coetzee, WITS; Bob Cook, ORNL; Paul Desanker, UVa; Dozie Ezigbalike, Univ. of Botswana; Leon Herbert, WITS; Chris Justice, UVa; Dave Landis, GSFC; Jeff Morisette, GSFC; Jaime Nickeson, GSFC; Jeff Privette, GSFC; Sue Ringrose,

(Continued on page 36)

Summary of the SAFARI 2000 wet season field campaign along the Kalahari Transect

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Introduction

An international group of researchers completed an intensive field campaign in Botswana and Zambia between February 28 and March 18, 2000. The activity was the second of four planned intensive campaigns of the Southern Africa Regional Science Initiative 2000 (SAFARI 2000; Swap and Annegarn, 1999). This initiative was designed to facilitate and link research on the regional land-atmosphere system with an emphasis on terrestrial emissions (biogenic, pyrogenic and anthropogenic), atmospheric modification and transport of these emissions and the consequences of subsequent deposition on the biogeochemistry of the regional ecosystems. A number of independently funded activities collectively constitute SAFARI 2000 including efforts from national research programs in the region, the International START[1] Secretariat and NASA.

The wet season campaign summarized here consisted of ground, tower-based and remote sensing measurements. The main objective was to characterize land surface processes and land-atmosphere exchanges during the growing season along a land cover gradient in the region. The participants represented institutions both in the region and around the world. The research activities spanned plant physiology, ecological and hydrological processes, meteorology, atmospheric characterization and ground validation of NASA EOS data products.

The field sites were located along the IGBP[2] Kalahari Transect (KT) [Chanda *et al.*, 1998; Ringrose and Chanda, 2000; Scholes and Parsons, 1997]. This is one of several Terrestrial Transects designated for studies of global change issues using a coordinated set of field sites [Steffen, 2000] covering large areas (on the order of 1000 km) and spanning significant variation in a major environmental or land-use factor. The KT extends over a large rainfall gradient (200 to 1000 mm/year mean annual rainfall) in an area of uniform soils, the Kalahari sands, albeit with some local soil variation associated with pans and subsurface duricrusts. Conceptually, the KT extends from equatorial forest in Congo-Brazzaville to subtropical, arid shrubland of the Kalahari desert in south-western Botswana and adjoining areas of South Africa and Namibia, although the northern portion has not yet been as intensively studied. The "rapid assessment" approach to the present campaign was designed to allow near-synoptic sampling of the KT gradient.

The campaign started on February 28 in Mongu, Zambia with a group of 14 researchers. This group proceeded to four sites in Botswana where they were joined by researchers from the University of Botswana, the Botswana Meteorological Services and Ministry of Agriculture and other institutions. The campaign ended on March 18 at Tshane in southern Botswana. Students from the University of Botswana also participated in measurement activities at the Tshane site. After the campaign a seminar was held at the University of Botswana where the participants discussed their work and shared preliminary findings. The complete list of participants with contact information is available through the SAFARI 2000 web page (http://safari.gecp.virginia.edu).

The field sites in Botswana had received above-average rainfall at the time of the campaign. This was associated with tropical cyclone Eline, an Indian Ocean storm which led to flooding in the eastern part of the region. In contrast, the Mongu, Zambia site had received slightly below normal rainfall at the time of the campaign.

[1] Global Change System for Analysis, Research and Training (START).

[2] International Geosphere-Biosphere Program (IGBP).

Field Sites

Sites

Figure 1 shows the location of the five field sites and the extent of soils dominated by Kalahari sands as delineated in the FAO soils dataset [FAO, 1995]. All sites are on the southern African plateau with elevations of about 1000 meters. The sites were selected to span a significant portion of the rainfall gradient in the region. We list the sites below in order of north-to-south.

Kataba Forest, Mongu, Zambia — ***15.438 South; 23.253 East***

The site is in a forest reserve approximately 20 km south of Mongu. It is one of the EOS Validation Core Sites and was recently augmented with a climb-up 30 m tower amidst the 12 m tall canopy. The vegetation cover is Kalahari woodland dominated by *Brachystegia spiciformis* with a sparse woody understory. At the regional scale, these woodlands are interspersed with large, flat grasslands (dambos). Mean annual rainfall is about 880 mm. Activites at this site were coordinated by Mukufute Mukelabai of the Zambian Meterological Deptartment.

Pandamatenga Agricultural Station, Pandamatenga, Botswana — ***18.655 South; 25.500 East***

This site is approximately 100 km south of Kasane, Botswana. The vegetation cover is an open woodland dominated by *Ricenodendron rautanenii*, *Baikiaea plurijuga* and *Burkea africana* with patches of high grass biomass. It is adjacent to large agricultural areas and undergoes light grazing. Mean annual rainfall is about 700 mm.

Harry Oppenheimer Okavango Research Centre, Maun, Botswana — ***19.923 South; 23.594 East***

This site is about 20 km northeast of Maun in a woodland managed by the Harry Oppenheimer Okavango Research Centre (HOORC). SAFARI activities were focused in an area approximately 3 km from a walk-up flux tower operated by the HOORC in collaboration with the Max Planck Institute. Some measurements were repeated at both sites to facilitate comparisons. Vegetation cover at both sites is mopane woodland (*Colophospermum mopane*) although the SAFARI site had lower tree heights and patches of *Terminalia sericea* thicket. Mean annual rainfall is about 460 mm. Elmar Veenendaal of the HOORC hosted the activities at this site.

Okwa River Crossing, Botswana — ***22.409 South; 21.713 East***

This site is located where the Trans-Kalahari Highway crosses the Okwa River bed, approximately 80 km south of Ghanzi, Botswana. This site has some topographic variation and soil characteristics which distinguish it from the surrounding landscape. The vegetation cover is an open shrubland cominated by *Acacia mellifera* and *Grewia flava* with scattered short trees. Mean annual rainfall is about 400 mm.

Tshane, Botswana — ***24.164 South; 21.893 East***

This site is located approximately 15 km south of Tshane, Botswana. The University of Botswana has a number of research activities focused in this area. The vegetation cover is open savanna dominated by *Acacia luederitzii* and *Acacia mellifera*. Mean annual rainfall at Tshane is 365 mm.

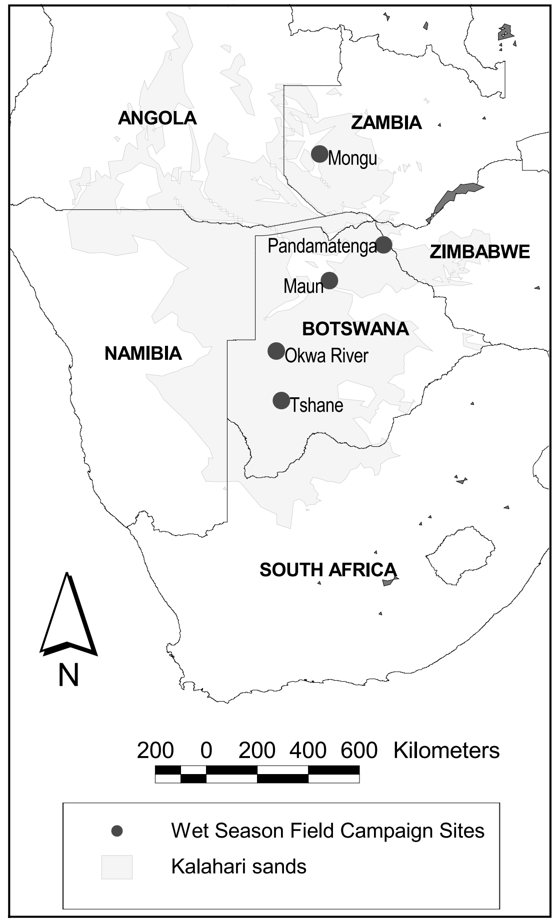

Figure 1. Map of field sites and the extent of Kalahari sands as delineated in the FAO Soil Map of the World.

Field Activities

The activities are summarized here by category. The primary researchers for each activity are indicated.

Meteorology

Botswana Meteorological Services[3] personnel recorded standard meteorological observations (wet and dry bulb temperatures, wind speed and direction) at 30 minute intervals at each of the sites within Botswana. Instruments were deployed adjacent to the site where the other groups were sampling.

[3] Botswana Meteorological Services Team. Gaborone office: Oagile Alosoboloko, Edward Bojang, M. Butale, P. Lesolle, Fish Modimoopelo, T. Morebodi, E. Motlamme. Francistown: G.G. Mbaiwa. Maun: Keitumetse Monaka. Kasane: Masego Nkepu.

Meteorological data (30 minute averages) were also recorded on the portable tower (5-11 m, adjustable) used to measure canopy fluxes[4] (Figure 2).

Figure 2.
Portable flux tower at Okwa River crossing site. From left: Todd Scanlon, Mukufute Mukelabai and Lindsay Hutley. Tower is shown in its shortest configuration (5 m). It was extended to 11 m height in taller vegetation.

Leaf and Canopy Radiation

A number of instruments were used at each site to characterize canopy radiation and canopy properties, including leaf area index. At each site, sample points were distributed along three parallel transects extending 750 m, separated by 250 m and marked at 25 m intervals. Spectral properties of soil and of leaves of dominant over- and understory species were also measured. Table 1 lists the instruments with reference to the contact personnel for each measurement.

Table 1.

Measurement	Instrument
Canopy Properties (canopy transmission, leaf area,leaf orientation and clumping, % cover)	Licor Plant Canopy Analyzer LAI-2000[5,6,7]
	TRAC[7]
	Decagon Accupar ceptometer[5,6]
	Nikon Digital Hemispherical Camera[8]
	ASD Field Spectrometer[7]
	Kipp and Zonen Albedometer (near-infrared, shortwave)[7]
	Kipp and Zonen Net Radiometer (tower mount)[9]
Component Spectra (e.g. leaves, soil), canopy transmission spectra	ASD Field Spectrometer, Licor 1800 Spectrometer[5]

Vegetation Structure/Composition

Additional techniques were used to characterize the vegetation at a range of spatial scales. In some cases the same parameters were sampled with contrasting techniques (see Table 2).

Table 2.

Parameter	Technique
Tree/Shrub Cover/Basal Area and Composition	Stem map[10]
	Line Transects[11,12]
	Circular sample plots[13,14]
	Spherical Densiometer[10,14]
Landscape-scale Composition/Structure	Line transects[15]
Grass Composition	Line transects[12]
	Circular sample plot[13]
Grass Biomass	Quadrat clipping[10]
Root Distribution	Soil pit profile/root excavation[16]
Tree Age Structure	Tree Cores[10]

Leaf Processes

Dominant species were characterized ecophysiologically at four Botswanan sites [17]. CO_2 response and light response of

4 Todd Scanlon and John Albertson, University of Virginia; Lindsay Hutley, Northern Territory University.
5 Yujie Wang, Yu Zhang, Yuhong Tian and Kyarn Tabor, Boston University
6 Bob Scholes, CSIR.
7 Jeff Privette, NASA/Goddard Space Flight Center.
8 Gareth Robers, University College, London
9 Todd Scanlon and John Albertson, University of Virginia, and Lindsay Hutley, Northern Territory University.
10 Kelly Caylor, Lynette Sobehart and Peter Dowty, University of Virginia.
11 Jerry Ramontsho, Copper Sakhu and Kholly Keitshokile, Range Ecology, Botswana Ministry of Agriculture.
12 Chris Feral, University of Virginia.
13 Bob Scholes, CSIR, and Lindsay Hutley, Northern Territory University
14 Peter Frost, University of Zimbabwe.
15 Susan Ringrose, Universityof Botswana, and Wilma Matheson, Westwood International School.
16 Martin Hipondoka, Etosha Ecological Institute; Chipangura Chirara, University of Zimbabwe; and Maanda Lihavha, University of Venda.
17 Guy Midgley, National Botanical Institute, Cape Town; Brian Mantlana, University of Natal, Durban; and Lindsay Hutley, Northern Territory University.

photosynthesis and dark respiration were measured at three different temperatures spanning 10ºC (i.e. 25, 30 and 35º C) using a Licor 6400 Portable Photosynthesis System. The data were used to derive stomatal conductance, V_{cmax}, J_{max}, quantum efficiency, CO_2 and light compensation points. In addition, leaf size was measured in order to determine leaf specific area and mass. Leaf dimensions and specific leaf area of dominant species were also determined.

Canopy Fluxes[18]

Canopy energy, water and carbon fluxes were measured from tower-based sensors at all sites except Pandamatenga. One set of sensors was placed on the permanent tower at Mongu for the duration of the campaign (data from March 1-24) while a mobile tower system was used for short-term data collection (2-3 days) at the other sites (Figure 2). The mobile tower height was adjusted between 5-11 m depending on vegetation height at each site.

The sensor sets were identical and included an open-path CO_2/H_2O analyzer, a hygrometer, a 3D sonic anemometer, a net radiometer, an air temperature/humidity probe and a pyrgeometer.

Atmospheric Aerosols

A handheld multispectral sun photometer was used at each site to characterize atmospheric aerosols and estimate aerosol optical thickness. Measurements were taken throughout the day at 30 minute intervals except when prohibited by cloud cover[19].

Daytime total suspended particulate (TSP) samples were also collected at each site for stable isotopic analysis. A high volume pump was used to draw air through a glass fiber filter for 8 to 12 hours at a rate of approximately $1.4m^3/min$[20].

Biogeochemical Cycling

Specific biogeochemical processes were assessed using the techniques indicated in Table 3. Plant and soil samples were collected for chemical and isotopic analysis as described below.

Table 3.

Processes	Technique
N mineralization[21]	*In situ* isotope dilution method: soil extract to be analyzed in the laboratory.
Nitrification[21]	*In situ* isotope dilution method: soil extracts to be analyzed in the laboratory
Nitrogen fixation by soil microorganisms-soil crusts[21]	*In situ* acetylene reduction assay: gas samples to be analyzed in the laboratory
Hydrocarbon emissions[22]	Absorbent traps were used to collected hydrocarbon emissions from leaves and these will be analyzed by gas chromatograph-FID and mass spectrometer in the laboratory
NO_x emissions[22]	Soil samples were collected and NO production and consumption rates, and temperature and soil moisture response curves for NO will be measured in the laboratory using a chemiluminescence NO/NO_2 analyzer

Nitrogen cycling processes were analyzed, with a combination of *in situ* experiments and soil and plant sampling for laboratory analysis[21]. N mineralization, nitrification and N fixation were analyzed at all the sites except Pandamatenga. Mineralization and nitrification, as well as soil and plant sampling, were also analyzed at additional sites in Maun and Tshane, with different grazing intensities. Tree shrub and grass samples of all the common species were collected for isotopic and nutrient analysis. Soils under different functional types of plants and at different depths (0-5, 5-10, 10-15, 15-20, 20-30 cm) were collected for the same analysis, and KCl soil extracts were prepared in the field in order to analyze isotopic composition of ammonium and nitrate[21].

Leaf, twig, root and soil samples were collected at the Maun, Okwa River and Tshane sites for each of four vegetation types, grasses, trees, shrubs, forbs. Three additional sites representing different intensities of land use (e.g. grazing pressure) were also sampled[23].

[18] Todd Scanlon and John Albertson, University of Virginia; Lindsay Hutley, Northern Territory University.
[19] Mukufute Mukelabai, Zambia Meteorological Department.
[20] Kaycie Billmark, University of Virginia and Marguerite Barenbrug, University of the Witwatersrand.
[21] Julieta Aranibar, University of Virginia.
[22] Luanne Otter, CSIR
[23] Chris Feral, University of Virginia.

Soil Moisture and Heat Flux

In conjunction with the mobile tower only, open and under-canopy patches were instrumented with soil heat flux plates (5 cm depth), TDR soil moisture probes (0-30 cm) and soil temperature thermocouples (2.5 and 7.5 cm). Thirty minute average values were recorded over the duration of flux tower sampling[24].

A second set of soil moisture and temperature sensors were semi-permanently deployed near the Mongu flux tower[25]. The profile includes five TDR soil moisture probes (Campbell Scientific CS615) and three thermisters (Campbell Scientific 107L) placed at the following depths: 5, 15, 30, 60 and 125 cm. The profile also includes a soil heat flux plate (Campbell Scientific HFT3) deployed at a depth of 10 cm. Ten-minute samples are averaged and recorded every 30 minutes.

Soil samples were collected at different depths to estimate bulk density, total organic matter content, texture, particle size distribution and cation exchange capacity. Seven surface soil samples were collected at random locations for laboratory analysis[25].

Spatial variability of soil moisture in the surface layer (0-30 cm) was also characterized over approximately one hectare at the Mongu, Pandamatenga and Okwa River sites. A handheld TDR probe was used to sample locations on a regular grid of points[26].

Remote Sensing Data

Remote sensing data are critical to the SAFARI effort given the large study area and its relative inaccessibility. Moreover, validation of EOS Terra products was the primary goal of several campaign participants (e.g., Privette, 2000). Thus, arrangements were made with several Terra teams (MODIS, MISR and ASTER) for acquisitions over the study sites simultaneously with the ground campaign. Landsat 7, AVHRR and SeaWiFS data and products were also acquired. Finally, IKONOS images were requested through the NASA Science Data Buy program. The various data sets are available for the Mongu site through the EOS Validation Core Site WWW page (URL: modis-land.gsfc. nasa.gov/val/ index.asp) as data policies permit. Imagery and products for other sites will be available through the Mercury system at the Oak Ridge DAAC (URL: mercury.ornl.gov/safari2k/ search.htm) and distributed on SAFARI CD-ROMs[27].

Data Availability

Data and metadata from the wet season campaign will be available through the web-based Mercury system at the Oak Ridge DAAC. Some data will be immediately and openly available. Remaining data will be made available in accordance with the SAFARI 2000 data sharing and release policy. In addition, the data will be openly disseminated on SAFARI CDROMs in a timely manner.

Conclusions and Next Steps

The three-week Kalahari Transect campaign resulted in an extremely rich data set in the relatively data sparse Kalahari region. Some of the first leaf and canopy level flux/conductance measurements for the region were obtained, and canopy structural information was rigorously measured at multiple spatial scales. Data analysis is presently underway and will be reported both in peer-reviewed literature and through conference reports. Interested readers are urged to contact coauthors of this article or refer to the SAFARI 2000 WWW page (URL: safari.gecp.virginia. edu) for updated information.

The wet season campaign will be followed by a dry season/biomass burning field campaign in August-September 2000. Although some ground-based activities will occur at that time, most activities will focus on atmospheric measurements. This will include extensive airborne sampling with multiple aircraft including the ER-2. Researchers interested in participating in these campaigns or other SAFARI activities are encouraged to contact organizers via the SAFARI web page.

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[25] Ana Pinheiro, NASA Goddard Space Flight Center.

[26] Kelly Caylor and Lynette Sobehart, University of Virginia.

[27] Jeff Morisette, NASA Goddard Space Flight Center-University of Maryland.

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Satellites Used To Help Predict Deadly Disease Outbreaks

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NASA is providing new insights from space that may help health officials predict outbreaks of deadly water-borne cholera, a bacterial infection of the small intestine that can be fatal to humans.

Scientists have learned how to use satellites to track blooms of tiny floating plant and animal plankton that carry cholera bacteria by using satellite data on ocean temperatures, sea height and other climate variables. The work is described in a recent paper co-authored by University of Maryland Biotechnology Institute (UMBI) and NASA researchers that appeared in the Proceedings of the National Academy of Sciences.

"These experiments fulfill our hypothesis that cholera is associated with environmental conditions," said Dr. Rita Colwell, founder and former president of UMBI, and now Director of the National Science Foundation. She is presently on leave of absence from the University of Maryland, and is co-author of the cholera- tracking project paper.

The authors found that rising sea temperatures and ocean height near the coast of Bangladesh in the Bay of Bengal from 1992 to 1995 often preceded sudden growth, or "blooms," of plankton and outbreaks of cholera. Similar application of risk analysis developed by NASA using satellite data has also been used in the study of diseases such as malaria, Lyme disease and Rift Valley fever.

"When such a model for Bangladesh is extended to the global scale, it may serve as an early warning system, enabling effective deployment of resources to minimize or prevent cholera epidemics in cholera-endemic regions," according to Brad Lobitz, principal author of the paper and a contract scientist at NASA's Ames Research Center, located in California's Silicon Valley. The scientists correlated years of hospital cholera records from Bangladesh with sea temperature and ocean height data that came from a variety of satellites and surface observations.

"Satellites not only can measure water temperature and ocean height, but also can measure colors that indicate plankton and chlorophyll over a large sea area," Lobitz explained. "Tracking sea temperatures from ships and by other direct measurements is too expensive to be practical," he added.

Cholera may result in extreme diarrhea, vomiting and loss of water. Victims can die within a day or so unless body fluids

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Earth Science Enterprise Education Program Update

First Digital Earth Alpha Version Workshop Announcement

— *Steve Graham (steven.m.graham.2@gsfc.nasa.gov), Raytheon RITSS*

NASA, the US Geological Survey, and other Federal departments and agencies are seeking participants in developing a series of Digital Earth Alpha Versions to illustrate the vision of the Digital Earth www.digitalearth.gov and implement a subset of that vision as rapidly as possible. Alpha Version demonstrations will employ today's technologies and associated infrastructure to bring Earth information and tools into the hands of various user communities. Digital Earth Alpha Versions will focus on specific user communities—e.g., journalists, students, museum-goers, and governance organizations—and show how they can exploit geospatial information, technology, partnerships, and the National Spatial Data Infrastructure to significantly improve their decision-making and educational opportunities through greater understanding of the Earth at the global, national, and local levels. Climate and weather will be the overarching theme for the first Alpha Version implementations. Additional details on the Digital Earth Alpha Versions requirements and scenarios are available at URL: www.digitalearth.gov/alpha/

If you are interested in supporting this initiative, or wish to obtain more information, please visit the website above. The point-of-contact for this project is Mark Reichardt at (703) 648-5742. Additionally, if you would like to participate in building the Digital Earth Alpha Version, please contact Ann Carbin at (301) 286-6663 to reserve a seat at the Digital Earth Alpha Version Workshop to be held in the Washington DC area July 25-26, 2000. Additional details on the Workshop will be posted to www.digitalearth.gov in the near future.

Fifth Annual GLOBE Conference

Leaders from GLOBE countries around the world and GLOBE franchises in the United States will gather for the Fifth Annual GLOBE Conference, July 17-21 in Annapolis, Maryland, USA to discuss experiences and strategies for advancing the program. GLOBE scientists will provide reports on new science investigations, and on the status of research using student data, and education advisors will report on how the program can advance learning. The Science, Education, Franchise, and Country reports from the conference will be posted on the GLOBE website this summer. Additional information can be found at URL: www.globe.gov

Ninth Grader Wins First Thacher Scholarship For Earth Remote Sensing

Julia Greenberg, a ninth grader from Evanston Township High School, Evanston, Illinois, was selected as the first recipient of the Thacher Scholarship. The $4,000 award was announced at the NASA Student Involvement Program's (NSIP) Awards Dinner on May 9 in Washington, DC.

The Thacher Scholarship was founded in honor of Peter S. Thacher, an internationally recognized leader in promoting the use of remote sensing worldwide and former United Nations Assistant Secretary-General. He played a special advisory role for NASA and provided a unique and extremely valuable contribution to geographic information systems on local, regional, and global levels. Thacher died of brain cancer in April 1999.

Thacher's son, Shaw, awarded the scholarship remarking, "For those of you who did not know my father, he would have loved to have been involved in the NASA Student Involvement Program's Watching Earth Change competition. And, he would have felt honored and moved to have this scholarship established in his name."

Greenberg's paper, *The Die-Off of Mangrove Trees in the Saloum River*, was selected by a panel of judges, who reviewed six of the NSIP Watching Earth Change first place Center winner entries. According to Thacher, "this was not an easy process—all of these projects and papers are truly outstanding." Thacher added, "One paper, however, truly captured and described the connections and thinking my father believed in promoting and lived for—displaying the best use of remote sensing in better understanding the changing planet."

The Institute for Global Environmental Strategies (IGES) founded the scholarship

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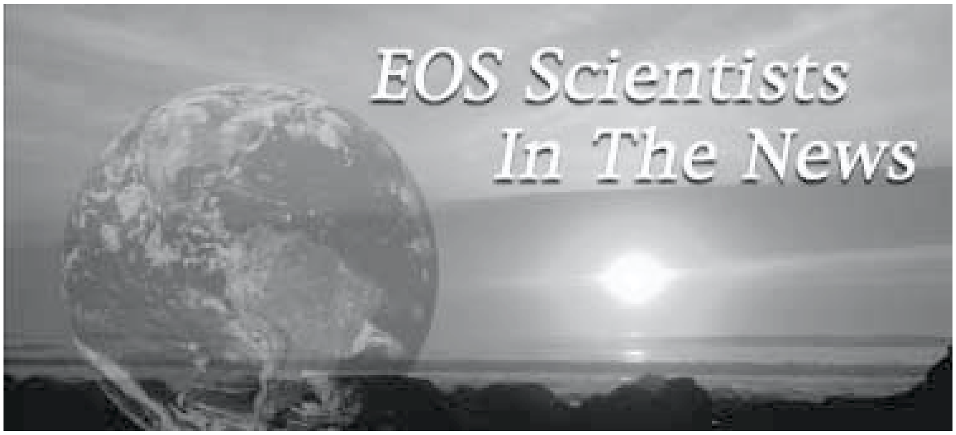

"Rivers of Rock," (July 2000) *Scientific American*. **Peter J. Mouginis-Mark** (University of Hawaii) and other researchers have turned to satellite imagery and computer models to help them more efficiently predict where volcanic mudslides called "lahars" may occur.

"Warming Effects to be Widespread," (June 12) *The New York Times*. **Jerry M. Melillo** (Marine Biological Laboratory) is one of the authors of a federal climate assessment on warming effects on the U.S. in the coming decades. The draft report analyzes effects on forestry, fresh water, farming, coastal areas, and human health.

"Future Looks Cloudy for Arctic Zone," (June 3) *Science News*. **Eric J. Jensen** (NASA Ames) called for more analysis of the data collected in the SAGE III Ozone Loss and Validation Experiment (SOLVE) of polar stratospheric clouds and their adverse effect on ozone. **Drew Shindell** (NASA GISS) commented on the value of global satellite data sets.

"La Niña is Dying. Or Is It?," (May 9) CNN.com. Oceanographer **Tony Busalacchi** (NASA GSFC) says that La Niña is not yet over but is expected to decay and die out towards the summertime, with its effects lasting into the second half of the hurricane season.

"Earth's High-Tech Checkup," (April 20) *The Washington Post* and *Reuters*. **Yoram Kaufman**, (NASA GSFC) says that Terra will provide improved understanding on how the land, sea, and air interact with each other and with clouds, vegetation, and airborne particles to influence global climate.

"The Truth is Down Here," (June/July 2000) *Smithsonian's Air & Space*. **Ralph Dubayah** (University of Maryland) said the Vegetation Canopy Lidar satellite will produce 3-D pictures of forests around the globe. **Bob Swap**, (University of Virginia) coordinator of the Southern Africa Regional Science Initiative says that region was chosen to validate the data from Terra because it has scientific measurement records dating back 100 years or more.

"Power of Nature's Atmospheric Cleanser Revealed," (June 1) *United Press International*. **Daniel Jacob** (Harvard Univ.) noted that a NASA airborne campaign in the Pacific last year has revealed the power of nature's own atmospheric cleanser, the hydroxyl radical. The mission also showed how pollutants from across the Northern Hemisphere can circulate over thousands of miles.

EOS Researchers:

Please send notices of recent media coverage in which you have been involved to:

Rob Gutro, EOS Project Science Office,
Code 900, Goddard Space Flight Center,
Greenbelt, MD 20771
Tel. (301) 441-4217; fax: (301) 441-2432
e-mail: rgutro@pop900.gsfc.nasa.gov

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Report on SAFARI 2000 Outreach Activities, Intensive Field Campaign Planning Meeting, and Data Management Workshop

Univ. of Botswana; Tim Rhyne, ORNL; Hank Shugart, UVa; Tim Suttles, Raytheon Corp.; and Bob Swap, UVa.

Summary Remarks

Through regional outreach activities, a regional planning meeting, and a data management workshop, preparations have been completed for the SAFARI 2000 Third Intensive Field Campaign. Outreach activities have provided the region with an understanding of the new satellite capabilities that are the subject of the satellite data validation component of SAFARI 2000. The IFC 3 Planning Meeting brought the science team together to focus on finalizing the logistics and operational aspects of the campaign. The Data Management Workshop resulted in agreement on a plan for the acquisition, early distribution, synthesis of 'golden days' subsets, and distribution and archival of SAFARI 2000 data. The stage is now set for IFC 3 to be conducted in August-September 2000 - the major activity of the SAFARI 2000 science initiative in southern Africa.

Researchers Take New York City's Temperature

— Cynthia O'Carroll (Cynthia.M.OCarroll.1@gsfc.nasa.gov), NASA Goddard Space Flight Center
— Kisha Wright (Kisha.Wright.1@gsfc.nasa.gov), NASA Goddard Space Flight Center

Researchers today announced key results of a two-year research effort to assess the vulnerability of New York City to climate change. Seven critical sectors addressed in this study are coasts, wetlands, infrastructure, water supply, public health, energy and institutional decision-making.

Drs. Cynthia Rosenzweig, Vivien Gornitz, Ellen Hartig, Richard Goldberg, and Reggie Blake of NASA's Goddard Institute of Space Studies, along with researchers from other institutions, present the results of the Metropolitan East Coast (MEC) at a conference held at Columbia University in New York City.

"Climate impacts in cities are multi-dimensional," said Rosenzweig, a Co-Leader of the MEC study. "Our goal is to provide critical information to assist the region's decision-makers to anticipate, prepare for and prevent the potentially serious impacts of climate events now and in the future."

Study results show that over the last 100 years the temperature has risen 2 degrees Fahrenheit. Scenarios from global climate modeling studies project additional warming for the New York Metropolitan Region throughout the 21st century, ranging from 4 to10 degrees Fahrenheit.

The effects of this warming trend will not be uniform across all sectors. The most direct health effect likely to be associated with a warming and more variable climate is an increase in summer-season heat stress, particularly among the poor and elderly.

A warmer climate is also likely to raise the demand for electricity and cause increased stress to the electric utility systems. Recommendations to decision-makers include educating the population on energy efficiency.

Other study results involve the coastlines and the delicate wetland areas due to sea-level rise. The already rising sea level in the MEC region is projected to rise 4.3 to11.7 inches over the next 20 years. This sea-level rise would lead to more storm damage and increased beach erosion. Higher sea levels and more damaging storm surges will impact fish and bird habitats in the wetland areas.

This study represents a unique collaborative effort that brings together key stakeholders, including state, regional, and local agencies, as well as environmental organizations, to address climate change and its impacts to ensure results were relevant and useful in all decision-making sectors. Stakeholders are institutions whose activities are and will be impacted by present and future climate variability and change and have a stake in being involved in research of potential impacts.

"A goal of the process has been to ensure that the results are relevant to the people that actually make the decisions that affect the city," said William Solecki, Co-Leader of the MEC Assessment and a geographer at Montclair State University, NJ.

The study of the Metropolitan East Coast (MEC) area is one of 16 regional components that contribute to the U.S. National Assessment: The Potential Consequences of Climate Variability and Change, organized by the U.S. Global Change Research Program. The goal of each regional assessment is to understand the impacts of climate change and variability on physical systems and human activities of a specific area of the United States. The Metro East Coast Assessment is the Regional Assessment that specifically addresses issues of climate change and cities. The National Science Foundation and Columbia University's Earth Institute provided major funding for the study.

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Satellites Used To Help Predict Deadly Disease Outbreaks

are replenished quickly. The seventh cholera pandemic began in 1961 and now affects six continents, according to the paper. A pandemic is an epidemic that occurs over a large region.

Sea height is important because tides reach further inland to affect more people who may drink or bathe in brackish water carrying cholera. "Bangladesh is very low and flat, and tidal effects are felt almost half way up into the country," said co-author Louisa Beck of California State University at Monterey Bay and a resident scientist at Ames.

"The 1992-to-1995 study is important because all the remote sensing satellite data are in the public domain," Beck said. "The main point is that we obtained the data at no cost because it is available on the web."

"In most years Bangladesh has two cholera outbreaks," Lobitz said. "These are in the spring and fall." The authors discovered that the sea surface temperatures show an annual cycle similar to the cholera-case data.

The effort was a cooperative project between NASA's Office of Life and Microgravity Sciences and Applications and UMBI. The study was also supported by grants from the National Institutes of Health and the Environmental Protection Agency. The other authors include Byron Wood, Ames; Anwar Huq, UMBI; and George Fuchs and A. S. G. Faruque, the International Centre for Diarrhoeal Disease Research, Bangladesh. More information about the cholera-tracking project is on the Internet at: geo.arc.nasa.gov/sge/health/projects/cholera/cholera.html

The researchers used data from three Earth-observing satellites in the study: a National Oceanographic and Atmospheric Administration weather satellite, the SeaWiFS instrument aboard the SeaStar (OrbView-2) satellite, and the U.S.- French TOPEX/Poseidon oceanography satellite. Data from SeaWiFS and TOPEX/Poseidon are provided through NASA's Office of Earth Sciences, which is dedicated to studying how natural and human-induced changes affect the Earth's global environment.

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Earth Science Enterprise Education Program Update

First Digital Earth Alpha Version Workshop Announcement

and obtained additional contributions from Mrs. Peter S. Thacher, WT Chen & Company, Inc, and Mr. & Mrs. Andrew Chopivsky. IGES President, Nancy Colleton, stated, "We see this as the beginning and hope to grow the scholarship funds for next year. We'd also like to work with partners to establish scholarships for the other NSIP competition areas too."

For more information on NSIP, see http://www.nsip.net; for more information on the Thacher Scholarship, see http://www.strategies.org .

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Reserchers Take New York city's Temperature

The study area for the Metro East Coast Assessment covers the 31 counties of the New York City metropolitan region. The area consists of 13,000 square miles, with jurisdictions involving 1,600 cities, towns and villages in the three states of New York, New Jersey, and Connecticut. The total regional population is 19.6 million, of which 7.3 live in New York City.

Other organizations participating in this study include: Columbia University's Earth Institute, Lamont Doherty Earth Observatory and School of Public Health, Montclair State University, New York University and SUNY Stony Brook.

For more information about the MEC project, access the website at metroeast_climate. ciesin.columbia.edu

The GISS web site regarding their contribution to the National Assessment is at www.giss.nasa.gov/projects/metroeast/

The web site for public comment on the draft National Assessment report is at www.gcrio.org/NationalAssessment/

EOS Science Calendar

September 7-8
LASP, University of Colorado, Boulder, CO. Contact bob Schutz, e-mail: schutz@csr.atexas.edu

September 12
8:30 a.m. - 4:00 p.m., Aqua Science Working Group meeting, Goddard Space Flight Center, Greenbelt, MD, building 32, room E103/109. Contact: Claire Parkinson, e-mail: clairep@neptune.gsfc.nasa.gov.

September 13, 14, 15
SORCE Science Team Meeting, The SilverTree Hotel, P.O. Box 5009, Snowmass Village, CO. Contact Gary Rottman, e-mail: Gary.Rottman@lasp.colorado.edu or Kathy.Lozier@lasp.colorado.edu for information.

September 19-21
HDF/HDF-EOS Workshop IV, Landover, MD. Contact Richard Ullman, e-mail: ullman@gsfc.nasa.gov.

September 20-22
CERES Science Team Meeting, Huntsville, AL. Contact Gary Gibson, e-mail: g.g.gibson@larc.nasa.gov.

September 25-27
NSIDC DAAC User Working Group Meeting, National Ice Center, Suitland MD. Contact: Ron Weaver, e-mail: weaverr@kryos.colorado.edu

September 25-29
Joint SAGE III Ozone Loss and Validation Experiment (SOLVE) and third European Stratospheric Experiment on Ozone (THESEO 2000) Science Team Meeting, Palermo, Italy. Contact Paul Newman, e-mail: newman@notus.gsfc.nasa.gov.

Global Change Calendar

July 24-28
IEEE 2000 International Geoscience and Remote Sensing Symposium, 20th Anniversary, Hilton Hawaiian Village, Honolulu, Hawaii. Conference website URL: www.igarss.org.

July 24-29
International Radiation Symposium (IRS-2000), Saint Petersburg State University, St. Petersburg, Russia. Contact conference coordinator, Evgenia M. Shulgina, St. Petersburg State University, Research Institute of Physics, 1 Ulyanovskaya, 198904, St. Petersburg, Russia; Fax: +7 (812) 428-72-40; e-mail: Evgenia.Shulgina@ pobox.spbu.ru; or shulg@troll.phys.spbu.ru.

August 6-17
31st International Geological Congress & Scientific Exhibits, Rio de Janeiro. Contact Tania Franken, tel. 55 21 537-4338; Fax: 55 21 537-7991, e-mail: geoexpo@fagga.com.br, URL: /www.31igc.org.

October 9-11
First International Global Disaster Information Network (GDIN) Information Technology Exposition & Conference, Honolulu, Hawaii. Contact: dehring@erim-int.com, tel. (734) 994-1200, URL: www.erim-int.com/CONF/conf.html.

October 9-12
SPIE's Second International Asia-Pacific Symposium on Remote Sensing of the Atmosphere, Environment, and Space Sendal, Japan. Contact SPIE, URL: www.spie.org/info/ae/.

October 16-20
ERS-ENVISA Symposium "Looking at our Earth in the New Millenium," Gothenburg, Sweden. Call for Papers. Contact Prof. J. Askne, e-mail: askne@rss.chalmers.se; URL: www.esa.int/sympo2000/.

October 24-26
Tropospheric Aerosols: Science and Decisions in an International Community—A NARSTO Technical Symposium on Aerosol Science, Querétaro, Mexico. Contact: Norman Mankim, tel. (775) 674-7159; e-mail: normanm@dri.eud; URL: www.cgenv.com/Narsto.

November 6-8
14th International Conference and Workshops on Applied Geologic Remote Sensing, Las Vegas. Contact: e-mail: wallman@erim-int.com, URL: www.erim-int.com/CONF/GRS.html.

November 22-24
Vision, Modeling and Visualization 2000, Saarbruecken, Germany. Contact Hans-Peter Seidel, e-mail: hpseidel@mpi-sb.mpg.de, URL: www.mpi-sb.mpg.de.

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February 6-9
AVIRIS Earth Science Workshop, Jet Propulsion Laboratory. Contact Robert Green, e-mail: rog@spectra.jpl.nasa.gov, URL: makalu.jpl.nasa.gov.

April 8-11
GWXII: The XIIth Global Warming International Conference & Expo, 2001 Annual conference: KYOTO Compliance Review. Cambridge University UK. Call for Papers. For abstracts submission see URL: www.GlobalWarming.Net; tel. (630) 910-1551; Fax: (630) 910-1561; e-mail: gw12@GlobalWarming.Net.

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