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Editor's Corner

Nearly seven months into the fiscal year, Congress passed and the President signed the budget for FY96 on April 24. The NASA budget for the Office of Mission to Planet Earth was $535.3 M for EOS flights, $241.2 M for EOSDIS, and $248.2 M for science, including both the research and analysis program as well as EOS Interdisciplinary Science (IDS) investigations. This budget represents a $91 M reduction to the Office of Mission to Planet Earth from that requested by President Clinton, and is consistent with that agreed to by the Appropriations Conference Committee of the House and Senate, which voted to decrease the EOS budget by $75 M, eliminate NASA funding of CIESIN ($6 M), and give a blanket reduction to NASA overall (of which $10 M was assigned to Mission to Planet Earth).

President Clinton's budget request for FY97 was submitted to Congress on March 19, and is currently in the process of undergoing hearings and markups by the House and Senate. The budget request for Mission to Planet Earth includes allocations of $585.7 M for EOS flights, $261.1 M for EOSDIS, and $277.1 M for science, including $50 M for purchase of MTPE-related data from the commercial sector.

On April 17, NASA resumed work with TRW Space and Electronics Group of Redondo Beach, CA on two "common" spacecraft (PM-1 and Chemistry-1), valued at $398.7 M. This contract was mired in protests, filed by losing bidders Hughes Space and Communications Co. of Los Angeles, and Lockheed Martin Missiles and Space of Sunnyvale, CA. The protests were only recently resolved by the General Accounting Office, which reviews all such protests. The contract includes two

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spacecraft along with options for two more spacecraft (for an additional $269.8 M), and permits work to resume in earnest towards a launch of EOS PM-1 in December 2000.

An advanced, lightweight scientific instrument designed to produce visible and shortwave infrared images of Earth's land surfaces has been selected as the focus of the first New Millennium Program mission selected by the Office of Mission to Planet Earth. The new Advanced Land Imager instrument, called EO-1, will demonstrate remote sensing measurements of the Earth consistent with data collected since 1972 from the Landsat series of satellites. In addition, it will acquire data with finer spectral resolution, a capability long sought by many elements of the Earth observation data user community, and it will lay the technological groundwork for future land imaging instruments to be more compact and less costly. The total NASA cost of this first New Millennium Earth science mission, including its Small Expendable Launch Vehicle, has been capped at $90 million. Launch is planned for late 1998. The current mission operations concept for the New Millennium flight has the spacecraft flying autonomously several minutes ahead of the ground track flown by the planned Landsat 7 satellite, to provide accurate paired scene comparisons between the new and the traditional observing technologies. Evolutionary versions of the Advanced Land Imager would be candidates for flight on future generations of EOS missions, beginning with the AM-2 spacecraft.

At the Payload Panel meeting in Annapolis last November, I outlined a tentative schedule for development of Algorithm Theoretical Basis Documents (ATBDs) for many of the instrument science teams of EOS. These 30-40 page documents, to be developed for each data product, should describe in detail the granules and metadata to be included, all internal and external data product flows to be utilized, a physical and mathematical description of the algorithm, variance or uncertainty estimates, and practical considerations, such as calibration and validation, exception handling, quality control, and diagnostics. Although closely related algorithms may be combined into one document, an ATBD must be prepared for each algorithm some 4-5 years before launch, at which point it will be reviewed through a written as well as a panel review process.

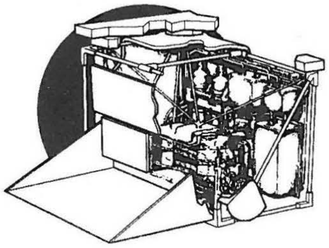
All EOS AM-1, LIS, and SeaWinds teams developed ATBDs in February 1994. These documents were subsequently reviewed and are now available on the World Wide Web. These teams are now expected to revise their ATBDs by August 16 for a second round of reviews; this time emphasizing the theoretical basis of the algorithms as represented in the flight-ready software that is now being developed. In addition to the AM-1, LIS, and SeaWinds science teams, I intend to initiate the first round of ATBD reviews for the following teams that have not yet developed ATBDs: AIRS/AMSU/MHS, ACRIM, AMSR, Data Assimilation, and SAGE III. These teams are expected to deliver their ATBDs to the Project Science Office by November 15. This process is extraordinarily valuable to the science teams and engages the larger scientific community, both nationally and internationally, in the process of providing feedback on approaches to routine data reduction from EOS sensors.

Finally, I would like to report that Dr. Piers Sellers, AM Project Scientist and Interdisciplinary Science Team Principal Investigator, has been selected as an astronaut candidate. He was selected as part of a class of 35 out of 2200 applicants, and will be leaving Goddard Space Flight Center, where he has worked for the past 14 years, for Johnson Space Center in Houston. He reports in August for a two-year training program, after which point he will start training for a specific spaceflight assignment. It is my distinct pleasure to have worked with him over the past several years, and to have witnessed the culmination of his dream to become an astronaut. For his many scientific accomplishments, he was recently elected a Fellow of the American Geophysical Union (see other significant awards elsewhere in this issue). On behalf of the Earth Science and especially Goddard scientific community, I would like to extend my best wishes for his continued success in future endeavors, and look forward to his return to Goddard after completion of his years as an astronaut.

—Michael King
EOS Senior Project Scientist

Atmospheric Infrared Sounder (AIRS) Science Team Meeting

— **George Aumann** (hha@airs1.jpl.nasa.gov), AIRS Project Scientist



The AIRS team held a very informative meeting at Santa Barbara, CA on February 27-29, 1996. Following is a brief summary of the meeting presentations.

The next AIRS team meeting will be held on June 25-27, 1996 in the NOAA Building #3 in Silver Spring, MD. Details will be provided to AIRS team members via e-mail about a month before the meeting.

General Information

Mous Chahine, AIRS Science Team Leader, reported on the EOS status.

1) Restructuring is anticipated for the data processing system (EOSDIS) starting with the EOS PM-1 mission. This restructuring may change the organizational responsibility for and/or physical location of the operational (routine) AIRS data processing facility. The restructuring will not change the responsibilities of the AIRS Science Team or the Team Leader Computing Facility with respect to delivering the algorithms and the operational retrieval software system, developing new data products, and making sure that the data processing generates valid data.

2) The New Millennium technology development of QWIP detectors, MMIC radiometers, and small, 45 K 0.5 W coolers will benefit a lightweight follow-on Integrated Multispectral (infrared/microwave) Atmospheric Sounder, IMAS.

3) IMAS specifications include the following functional requirements related to science:

    a) specifications for the infrared wavelength coverage, spatial and spectral resolution, signal-to-noise ratio, and calibration accuracy of IMAS will be the same as the AIRS specification.

    b) the microwave channels of IMAS will include the 54 GHz channels of the AMSU-A, but the 24 and 31 GHz channels will be deleted. Instead we will have about six 118 GHz channels (picked by Staelin) to replace the current single 150 GHz channel of AMSU-B. There will be about six channels in the 183 GHz region. The 118 GHz and 183 GHz channels will have the same footprint as the infrared channels (1.1 degree), the 54 GHz channels will have a 2.5 degree footprint (all dimensions refer to the full-width-at-half-peak). Since the infrared and microwave channel footprints are all scanned with the same scan mirror motor (the antennas in the current concept are on opposite output shafts of the motor), the spatial co-alignment of the infrared and microwave channels should be better than what we can do with the separate AMSU, AIRS, and MHS units.

4) Details of the Brazilian offer to build a copy of the AMSU-B for the EOS PM-1 spacecraft are being worked out. The proposed reconfiguration of an AMSU-B copy with the 150 and 183 Ghz channels, but without the 89 GHz channel, has been accepted by the EOS PM project.

5) LORAL has been bought by the Lockheed/Martin group, pending some antitrust investigations.

Fred O'Callaghan, AIRS Project Manager, reported on the status of the AIRS hardware and presented some details of the IMAS design concept. All major subcontracts for AIRS are in place. The Engineering Model (EM) CDR (Critical Design Review) was held in March 1996, the CDR for the PM-1 model will be in January 1997. Testing of the EM will be completed by the middle of 1997.

The IMAS will use new technology (QWIP, MMIC, small 45 K 0.5 W cooler, SiC lightweight structures and, possibly, information-preserving data compression) to combine the functionality of the AIRS, AMSU, and MHS into an integrated system. As much as possible the IMAS will build on the experience with and possibly component inheritance from AIRS. The goal is to fit the IMAS into an 0.8 x 0.9 x 0.4 meter volume, mass 110 kg, 100 W power, and 0.3 Mbps data rate.

Bjorn Lambrigtsen, JPL AMSU/MHS instrument representative, presented the AMSU-A and MHS status.

a) The EOS PM-1 AMSU instrument CDR and Calibration Peer Review were scheduled for April 16-18, 1996. The plan for the characterization of the AMSU antenna pattern was not adequate.

b) There was a choice of accepting an AMSU-B copy without either the 89 Ghz or the 150 Ghz channel. Since the AMSU 89 GHz channel is available, and we expect by the year 2001 to have many years of NOAA experience in comparing the AMSU 3.3 degree and AMSU-B 1.1 degree 89 GHz channels, retaining the 150 GHz channel was the right choice.

George Aumann, AIRS Project Scientist, announced the start of the AIRS home page at http://www-airs.jpl.nasa.gov. The AIRS home page is part of an educational outreach program. The home page includes papers giving details of the design of the AIRS instrument, the retrieval algorithms and the data processing system. Science Team members are encouraged to check it out and submit comments and contributions.

Core Retrieval Algorithm Developments

Joel Susskind discussed improvements in the GSFC retrieval code, since its delivery to the Team Leader Facility at JPL on December 15, 1995. Uncertainty of ozone amount is now included in the AIRS noise covariance matrix. The latest retrieval revision also solves for surface emissivity as a function of wavelength at day and night. Many retrieval options can be selected via a name list.

Mitch Goldberg gave an update of NOAA/NESDIS's AIRS core algorithm development:

a) The software, including principal component regression, was delivered to JPL on December 15, 1995. Evaluation of pseudo channels for the first guess solution is continuing. Larry McMillin, who designed the cloud-clearing module of the NOAA algorithm, pointed out that the accuracy of the cloud-cleared data is limited by the microwave channels of the AMSU.

b) Work on adding rocketsonde extensions to the NOAA matchup profiles has been completed, but the data have not been transferred to JPL.

Allen Huang discussed the Spatial and Spectral Simultaneous Retrieval Analysis developed in collaboration with Bill Smith at the University of Wisconsin. Unlike the NOAA and GSFC algorithms, which remove the effects of clouds with a cloud clearing algorithm using a 3 x 3 footprint pattern, this algorithm attempts to account for the effects of clouds. Retrievals under partly cloudy conditions can thus be accomplished with a single AIRS footprint. Retrieval accuracy using a single footprint under clear conditions is 1 degree K, but performance degrades significantly under cloudy conditions. The algorithm delivered in December 1995 works with night-time data only. The algorithm has to be modified to handle the reflected sunlight for day-time data. The higher spatial resolution obtained from single-footprint retrievals (versus 3 x 3 patterns) makes this algorithm an interesting candidate for mesoscale research.

Phil Rosenkranz has tried a version of the "microwave first guess" algorithm using DMSP SSM/T and SSM/T2 data (54 Ghz and 183 Ghz) to demonstrate the feasibility of single-footprint water vapor profile retrievals. The ability of the algorithm to reproduce the different moisture patterns at different pressure levels is very encouraging. The AMSU-A and MHS data from the EOS PM mission will have the same frequency coverage as the SSM/T and SSM/T2, but the spatial resolution will be a factor of three higher.

Larrabee Strow discussed the status of the fast transmittance algorithm and the water vapor spectroscopy. CO_2 is treated as a fixed mixing ratio gas in the rapid algorithm and a mixing ratio has to be selected. Mous Chahine pointed out that a change in the CO_2 mixing ratio of about 5 ppm can be detected on a yearly time scale from the evaluation of tuning residuals. This concept has been tested with TOVS data.

Larry McMillin has started to develop the radiance-tuning algorithm for AIRS and demonstrated NOAA's current algorithm using HIRS2 data. Since the HIRS2 has 19 channels versus the AIRS 2400 channels, the approach needs to be modified. He needs AIRS simulated data for algorithm testing. George Aumann will develop a simulation concept.

Data Processing and Instrument Operations (DPIO) Developments

Denis Elliott, DPIO Manager, presented the status of the DPIO and the team algorithm plan. The first delivery of core algorithms from Science Team members was received on December 15, 1995. Integration of the algorithms into a single retrieval system is progressing. The AIRS retrieval system preliminary design review (PDR) will be held at GSFC in October 1996, in conjunction with an AIRS team meeting.

Ed Olsen presented details of the acceptance status and a first cut at resource requirements for the algorithms delivered to the Team Leader facility on December 15, 1995. NOAA, GSFC, and MIT made a full delivery; the University of Wisconsin delivered night-time retrieval capability only. Although the code was developed on four different processors, installation on a fifth processor, a SUN 1000/4 SuperSparc went smoothly. Memory and CPU resource requirements were evaluated. Relative CPU times per retrieval for the code as delivered by NOAA, GSFC, and Wisconsin are 1 : 3 : 50. Typical tropospheric retrieval accuracy under 50% cloud cover for the NOAA and GSFC code is 1 degree K rms for temperature and 10% for water profiles.

Sung-Yung Lee, Ed Olsen, Luke Chen and John Gieselman comprise the team working on restructuring the team algorithm, selecting the best modules, and designing *The AIRS temperature and moisture retrieval algorithm.* The first version will be available for testing in July 96. The software will ultimately be in Fortran 90.

Toni Palmieri and his team (A. Revilla, R. Davidson, S. Gaiser, E. Manning, B. Morrison, R. Oliphant, H. Stone, and B. Weymann) have developed a complete AIRS prototype system, called prototype 4.0. They demonstrated prototype 4.0 using simulated data sets, starting with data ingest of packets, conversion to Level 0 data, calibration coefficient determination, application of the calibration to create Level 1b data, and following with retrievals to create the Level 2 output data. The input data come from a mesoscale GCM model developed by E. Kalnay and co-workers at NOAA/NMC. Prototype 4.0 allows a choice between the NOAA and the GSFC retrieval as delivered on December 15, 1995. The first version of *The AIRS temperature and moisture retrieval algorithm* developed by Sung-Yung, was to installed in the system starting in April 1996. Access to the code by team members and/or their designated programmers (under strict configuration control) is expected to start this summer. Hands-on-training will be made available for programmers in special workshops.

Dave Gregorich reminded the team of the various simulated data sets currently on line. The next simulation will include clouds with spectral emissivity/ reflectivity dependence and simulations using the NOAA matchups (once they are received from Goldberg).

Mark Hofstadter showed model calculations of emissivity as function of wavelength for altostratus and cirrus clouds. The calculations were made with a modified Ackerman model (U. Wisconsin). For altostratus the deviations from a typical 0.98 emissivity are smaller than the emissivity variations created by the current data simulation. For cirrus clouds (optical depth 0.6) the calculated emissivity may be as low as 0.3, but is also spectrally relatively flat. Hofstadter has also started to simulate visible channel data using the prescription developed by Gautier/Shiren at UCSB.

George Aumann presented details of the AIRS infrared radiometric and spectral calibration. The spectral calibration is now exclusively based on the upwelling spectral radiance. The data simulation in support of the calibration algorithm is being implemented by Evan Manning. Steve Gaiser is writing the calibration software. The IR calibration is implemented in the prototype 4.0 system demonstrated by Tony Palmieri.

Catherine Gautier and Jang Shiren, UCSB, are working on the absolute calibration concept of the visible light AIRS channels. The calibration will depend on vicarious calibrations over White Sands, where the physical conditions are reasonably well understood, using theoretical radiance computations. Over any large sandy region, 50 km or bigger, they plan to intercalibrate with MODIS. An AIRS visible light calibration approach document is in preparation.

Research Algorithm Development

Joel Susskind showed total ozone retrievals from NOAA 9-11 between 1985-1991, using the HIRS 9.6 µm channel. The HIRS requires a guess of the emissivity (0.98 over ocean, 0.95 over land). Comparison with collocated SBUV data is very encouraging. The extension of this algorithm to ozone profile retrievals using AIRS is straightforward. The AIRS core retrieval algorithm explicitly solves for emissivity at several wavelengths in the 10 µm window area. In addition to total ozone burden on a 50 km spatial scale, Susskind expects AIRS to be able to distinguish between 2-3 layers of ozone in the upper troposphere and stratosphere.

Paul Van Delst and Hank Revercomb, U. Wisconsin, are developing ozone weighting functions using a Fast Jacobian calculation. This effort could directly support Joel Susskind's ozone retrieval algorithm.

Catherine Gautier is continuing to develop a cloud-altitude retrieval algorithm using visible data. The algorithm uses the AIRS3/AIRS1 wavelength ratio. This effort directly supports the diagnostic effort expected for dealing with low clouds in the infrared. Cloud height determination with ±200 m accuracy may be possible. ■

Kudos

We would like to congratulate these colleagues on their outstanding achievements in the world of science.

Outstanding Scientists Receive AGU Honors in 1996:

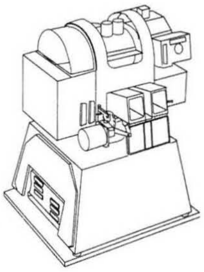
Robert E. Dickinson, University of Arizona, will receive the Roger Revelle Medal for a range of contributions to the atmospheric sciences from the climate of the early Earth to future climate change through development of general circulation models.

Inez Yau Sheung Fung, **Kuo-Nan Liou**, **Piers J. Sellers**, and **Richard S. Stolarski** were among those chosen as 1996 AGU Fellows.

James E. Hansen, Director of the Goddard Institute for Space Studies and an MTPE/EOS colleague, on his election to the National Academy of Sciences.

Philip N. Slater, a remote sensing scientist at the University of Arizona, and an MTPE/EOS colleague, received the 1995 William T. Pecora Award during ceremonies held on February 27, 1996 at the Eleventh Thematic Conference on Applied Geologic Remote Sensing in Las Vegas, NV. The 1995 award recognizes Slater's outstanding contributions to science and education and his sustained leadership, rigor, and service in the absolute calibration of optical remote-sensing instruments.

Clouds and the Earth's Radiant Energy System (CERES) Science Team Meeting



— **Bruce R. Barkstrom** (brb@ceres.larc.nasa.gov), Principal Investigator, NASA Langley Research Center
— **Gary G. Gibson** (g.g.gibson@larc.nasa.gov), NASA Langley Research Center

The 13th Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held March 13-15, 1996 at the NASA Goddard Space Flight Center (GSFC) in Greenbelt, MD. The focus of the meeting was CERES instrument status, algorithm development, and validation plans. The CERES instrument is designed to provide a climate data set suitable for examining the role of clouds in the radiative heat balance of the climate system. The CERES Science Team blends expertise in broadband radiometry, cloud and radiation remote sensing, and climate modeling. The Science Team guides the definition of the CERES instrument and science studies.

Michael King, EOS Senior Project Scientist, hosted the meeting and opened with an EOS science overview. He identified several key areas of EOS oversight and responsibilities related to CERES. The EOS Project Science Office will conduct peer reviews of instrument calibration and validation plans and will support field experiments and correlative measurement programs for validation. A second review of CERES Algorithm Theoretical Basis Documents, which should closely correspond to the flight version of the algorithms, is scheduled for the fall of 1996.

CERES Instrument Status

Leonard Kopia, Robert B. Lee III, and G. Louis Smith presented the instrument status report. The CERES instrument was delivered to GSFC in October 1995 and fully integrated on the Tropical Rainfall Measuring Mission (TRMM) spacecraft on February 14, 1996. Instrument weight and power are slightly below the TRMM allocations. Except for discrete Electro-Magnetic Compatibility (EMC) exceedances, the Proto-Flight Model (PFM) met all physical, electrical, and thermal performance requirements for TRMM. A waiver was approved for radiated emission and radiated susceptibility levels. Threshold levels in CERES (worst case) show a 60 dB margin between spacecraft allowable EMC limits for emissions and instrument sensitivity. The instrument noise is 2-3 counts with less than 1 count microstrain offset and no azimuthal variation of the offset. By comparison, the Earth Radiation Budget Experiment (ERBE) had 2.5 counts noise, 10-20 counts offset, and 30-40 counts offset due to azimuthal variation. Sensor sensitivity (Noise Equivalent Power; NEP) is five times better than ERBE (36 nW vs. 190 nW). Two calibration anomalies occurred: sensor gain variation with temperature (~0.4%), and existence of a second detector time constant. Both anomalies are being considered in the data reduction algorithms. The first full comprehensive spacecraft level testing is scheduled for April 22. EMI/EMC testing begins June 1, thermal/vacuum tests on June 27, and vibration testing on October 18. The spacecraft will be shipped to Japan on March 29, 1997, and will be ready for launch on August 1, 1997.

Several improvements were made to ensure compatibility with EOS spacecraft EMC requirements. Sensor changes to reduce susceptibility include the removal of a feedback capacitor in detector output signal lines, addition of signal buffers for better line impedance balance, and addition of filter networks to the high-voltage lines, high-voltage monitor lines, and bridge-balance control lines. These changes have resulted in a 20-30 times improvement in the radiated susceptibility response of the sensor electronics. A flexible ground strap was added between the rotating azimuth assembly and the pedestal to eliminate residual radiated emissions.

Pedestal harnesses and cable layout were reworked to provide better shielding and minimize cable lengths. Connectors were also reworked to improve shielding. Sensor units for Flight Model 1 (FM1) were aligned and characterized and are in the process of spectral characterization using the Fourier Transform Spectrometer. FM2 sensors are being aligned on the mounting plate. Sensor scan assembly is in progress and will be completed April 15 for FM1 and May 17 for FM2. The schedule shows 3.7 weeks of slack for FM1 delivery to EOS AM-1 on November 1, 1996, and 5.3 weeks of slack for FM2 delivery on January 10, 1997.

Data Management System

Jim Kibler presented the CERES Data Management System development schedule and a Release 1 software integration and test schedule. He also gave a comprehensive report on software development responsibilities and status, data products, and Release 2 issues for each Working Group. The ERBE-like Release 1 software, supporting data files, and test plan were delivered to the LaRC Distributed Active Archive Center (DAAC) on February 15, 1996. This is the first EOS code to be delivered to the DAAC. The remaining CERES Release 1 software has now been delivered to the Langley DAAC for testing and integration. This represents over 200,000 lines of code, and is another major delivery milestone on the way to launch. All CERES subsystems were delivered on or ahead of schedule, and early indications are that the integration of the software at the DAAC is going very well.

Instrument Working Group

The Instrument Working Group, led by Robert B. Lee III, focused on the validation plan, a review of Release 1 software, and discussion of Release 2 plans and issues.

Validation

The instrument validation and consistency plan was completed. Instrument data products include the filtered broadband shortwave (0.3 - 5.0 μm), total (0.3 - >100 μm), and window (8 - 12 μm) radiances. Validation plans encompass flight calibration analyses (internal calibration module and Mirror Attenuator Mosaic [MAM]), multi-channel comparisons (Inversion Working Group), multi-satellite intercomparisons (TISA Working Group[†]), single spacecraft cross-track and rotating azimuth plane (RAP) instrument comparisons, and geolocation/coastline detection studies.

Algorithms/Science

The Release 1 algorithm was delivered to the DAAC in February 1996. This code converts radiometric and housekeeping parameters and performs the geolocation calculations. The Release 2 (flight) version is being developed as a refinement of Release 1 plus solar and internal calibration collections for in-flight radiometric and geolocation calibration/validation. Dominique Crommelynck briefed the Team on the European Geostationary ERB (GERB) Experiment. He reviewed the instrument design and problem areas involving the detector, thermal isolation of array cells, and precision of the rotating scan mechanism. The GERB data should be especially useful in conducting diurnal studies, tracking cloud systems, and process/feedback studies.

Joint Cloud and Inversion (Top-of-Atmosphere Fluxes) Working Group

The Working Group was led by Bruce Wielicki in discussions of validation, cloud analysis methods, and software development. He showed a timetable through 1999 of software development goals for Release 1, Release 2, DAAC deliveries, optimizations, and pre- and post-launch validation of VIRS and MODIS.

Validation

Validation plans for all cloud and inversion subsystems were presented. Wielicki stressed the need for objective validation of the cloud mask. Pat Minnis offered McIdas as a way to get the surface observer cloud archives in real time for validation. He has October 86 data ready for use. Michael King suggested that ARM micropulse lidar data are available on the "web." The Group agreed, at Bryan Baum's suggestion, that the CERES cloud algorithm should also be able to work with current NOAA satellites so that we can validate with ARM data and other validation opportunities. In fact, the cloud algorithm should be decoupled from the rest of CERES so that we can validate with field experiment data, e.g.,

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[†] "TISA" means Time Interpolation and Spatial Averaging

lidar, radar, Experimental Cloud Lidar Pilot Study (ECLIPS) taken during non-ERBE months.

Jim Coakley suggested a consistency check by computing zonal averages of clear-sky temperature over sections of the oceans and examining them to see if they fall into other than normal distributions. Coakley also suggested using LITE and NOAA-11 coincidences for cloud height validation; using NOAA-12 data would be difficult because it is in a near-terminator orbit. Ron Welch focused on the need to check consistency of retrieved cloud parameters as you cross surface-type and cloud-type "boundaries." In late 1997, Surface HEat Budget of the Arctic Ocean (SHEBA) will provide good polar retrievals for validation. Wielicki stressed that vertical profilers were needed and discussed the feasibility of ground-based lidar profilers. Future field experiments were identified and prioritized for use in validating various retrievals. Several validation studies were identified and will be reported at future Science Team meetings.

Richard Green presented a plan to validate CERES data against the historical ERBS data by using Earth validation targets. The average nighttime longwave radiance over tropical ocean for a month was found to vary by only 0.5%. This quantity will provide an early validation of the CERES radiances. Green also showed that the average limb darkening can be established in the same manner, which is useful in validating the scanner offsets. He showed the limb-darkening function for both Nimbus-7 and ERBS and suggested that the difference could cause an inconsistency in the CERES ERBE-like product since the Angular Distribution Models (ADMs) are constructed with Nimbus-7 data and applied to ERBS radiances.

Algorithms/Science

The Release 1 cloud analysis code was delivered to the DAAC. Baum stressed the need for consistent treatment and feedback in all algorithms regarding bad data, missing data, partially processed data, etc. He summarized the lessons learned from Release 1. The EOSDIS Toolkit has initially represented a major overhead for resources, but it is expected that this approach will result in long-term savings. The team reconfirmed a past decision to exempt the Science Team from using the Toolkit for contributed code and instead delegate algorithm I/O issues to the software implementation staff. There was insufficient manpower to verify all contributed Release 1 algorithms, but for Release 2 it is mandatory that all algorithms be carefully checked out before being sent to the DAAC.

Pat Minnis showed global Visible Infrared Near-infrared Techniques (VINT) retrievals of cloud properties for one day of data. Minnis emphasized the need for the Co-Is to get all of the input before we can confidently verify that the CERES code gives results consistent with the off-line code. Steve Platnick showed water droplet radii retrievals and suggested that they were qualitatively the same as those derived from VINT. Minnis showed some preliminary results from his nighttime (10.7, 12, and 3.9 μm channels) cloud property retrieval algorithm, which is being developed for Release 2. Minnis' technique of using a lapse rate of 7 k/km for clouds lower than 2 km was adopted for the cloud algorithm. This will allow for the effects of inversions that are not picked up in the relatively coarse Meteorological, Ozone, and Aerosol (MOA) temperature profiles.

Ron Welch expressed concern about the cloud mask results from the first day of CERES cloud results. His code was run with a "global" algorithm specification rather than more specific types of algorithm specifiers (smoke, polar, etc.) that limit the geographical coverage. Larry Stowe showed Pathfinder results and gave a status report on Pathfinder. They have processed 15 months of AVHRR data for Pathfinder and will soon have 18 months. Baum presented some recent results of remote sensing of low-level clouds in marine polar air masses using AVHRR multispectral imagery and concluded that radiometric data from these clouds cannot be fully interpreted using a single cloud particle distribution.

Jim Coakley compared radiative fluxes from calibrated AVHRR and plane-parallel theory with observations. He applied the spatial coherence technique to identify similar, uniform, single-layer cloud regimes over the ocean for a month and formed a "global" composite of plane-parallel regions to extend the effective spatial scale. His study, along with an extension of his work by Norman Loeb, showed that when 1-D theory is used to infer cloud optical depth directly from observations at nadir, a systematic increase with solar zenith angle is observed. This increase is most pronounced at solar zenith angles greater than 63 degrees. On average, differences between observed and plane-parallel reflectances are more sensitive to changes in solar zenith angle than to viewing and azimuth angles. The differences are likely due to cloud 3-D effects.

Dave Randall compared Colorado State University (CSU) GCM results with ISCCP data and concluded that thin cirrus clouds are missed by current cloud retrieval algorithms. Thin cirrus clouds are at least as important radiatively as upper tropospheric water vapor. Changes in thin cirrus amount could strongly influence the climate. The CSU GCM is a good estimator of cloud occurrence with respect to ISCCP for optically thick ($\tau > 22$) clouds. For thin ($\tau < 3.6$) clouds, ISCCP detects significantly fewer clouds than the model. He suggested that, due to multiple cloud layers, ISCCP tends to overestimate optical thickness of high clouds.

Richard Green showed preliminary validation results of a new set of ERBE-like ADMs constructed from the Nimbus-7 data and the Radiance Pairs Method (RPM). The ERBE production ADMs show an erroneous 10% albedo growth from nadir to the limb, which was eliminated by the new ADMs except for viewing zenith angles greater than 70 degrees. Applying these new ADMs to ERBS data increased the global shortwave (SW) flux by 5 Wm^{-2} for a terminator orbit and resulted in a -5 Wm^{-2} change for a noon orbit. The longwave (LW) flux changes were within 1 Wm^{-2}. Validation of the new ADMs is continuing.

Alexander Ignatov, UCAR visiting scientist (representing Larry Stowe), showed aerosol products using NOAA AVHRR as a TRMM/VIRS prototype. He suggested that independent retrievals at 0.63 and 1.6 μm are desired to improve the overall aerosol dataset.

Surface and Atmospheric Radiation Budget (SARB) Working Group

Tom Charlock led SARB Working Group discussions on validation, initial Release 1 algorithm results, and Release 2 plans. For SARB, cloud physical and narrowband radiative properties data derived from cloud imagers such as VIRS or MODIS are used along with atmospheric temperature and humidity data in a radiative transfer model to calculate broadband radiative fluxes at the surface of the Earth, through the atmosphere, and up to the top of the atmosphere (TOA). Charlock reviewed the activities of the Atmospheric Radiation Measurement (ARM) Science Team and pointed out the synergies which exist between SARB activities and the ARM program.

Validation

Charlock and Charlie Whitlock presented a SARB validation plan which uses the CERES/ARM/GEWEX [Global Energy and Water Cycle Experiment] Experiment (CAGEX) and several surface networks. Whitlock briefly reviewed the first year of surface observations from the CERES Walker Tower validation site. A near-constant broadband surface albedo in combination with a false-color Landsat image dramatically illustrated the potential of the site for validating the ERBE-like SW and LW net surface products. The current focus is to finalize a near-term strategy for future operations. Michael King indicated that some surface sites will likely be enhanced with new instruments. Crommelynck described a balloon experiment in which radiation measurements were made for validating model calculations. Lessons learned from problems encountered in such experiments will be valuable in future measurement programs for validation.

Algorithms/Science

The SARB Release 1 code was delivered to the DAAC. Fred Rose presented results from several applications of the "flux constraint algorithm," which will be used to constrain the SARB radiative transfer computations with the TOA flux measurements obtained from CERES instruments. Comparison of model calculations with ERBE data showed that the application of the constraint algorithm improved the agreement significantly even though some differences persist. Application of the constraint algorithm to CAGEX data over the Oklahoma ARM/Cloud and Radiation Testbed (CART) site yielded similar comparisons. Tim Alberta reviewed the CAGEX datasets and presented comparisons of the radiative transfer computations from the Fu-Liou code with ERBE data. Significant biases were noticed in some of these comparisons for both clear-sky and all-sky SW fluxes.

CAGEX datasets are available to the science community for use and evaluation on the web.

Shashi Gupta presented the first results from Release 1 processing of surface-only, cloudy-sky LW fluxes for an hourly swath on October 1, 1986. The results were examined in terms of the meteorological inputs to the algorithms, and the sensitivities of the LW fluxes to these inputs. The results were consistent with the physical relationships, and agreed well with the climatological distribution of LW fluxes. Anand Inamdar (representing V. Ramanathan) reviewed the surface-only, clear-sky LW algorithm. He indicated that the group may use climatological data on cloud thicknesses from WMO atlases in developing a cloudy-sky surface LW algorithm.

Dave Kratz reviewed the state of the SW radiative transfer in clear atmosphere in light of the disagreements between model calculations and observations. He identified several possible causes for these disagreements including differences between the SW parameterizations used in the models and the line-by-line computations, the use of Lorentz line shapes in many models, and neglecting the far wings of lines and continua. He also reviewed the current status of the "surface only" SW and LW algorithms in Release 1 processing and the results from those algorithms.

Bob Cess presented a summary of recent studies that support his theory of anomalously high atmospheric SW absorption. Using the results of several researchers, Cess concluded that (1) plane-parallel models overestimate cloud albedo, (2) models overestimate surface SW absorption by overestimating surface insolation, (3) satellite-surface and stacked-aircraft measurements both indicate excess cloud SW absorption, (4) evidence indicates that the cause is macrophysical rather than microphysical, and (5) it is highly unlikely that observational evidence of excess SW absorption is due to satellite sampling errors.

Dave Randall presented results of studies with a Single Column Model (SCM). Meteorological observations from the Southern Great Plains (SGP) ARM/CART site were used to force the advective processes at the SCM boundaries. Results from the SCM were compared with observations of cloud formation and precipitation etc. from the ARM/CART site. The model is still in an early stage of development. Shi-Keng Yang (representing Jim Miller) presented results from simulations from the National Centers for Environmental Prediction (NCEP) model with a new SW parameterization based on Chou's work. Comparison with ERBE data showed improvement over earlier results, but significant differences still remained. Comparison of NCEP cloud amount with ISCCP showed significant biases off the west coast of South America, north of India, and off the west coast of South Africa. Some dynamics-related problems in the Tropics were suggested. Maurice Blackmon showed several new developments/improvements to the physics in an NCAR GCM (CCM3). A new deep convection scheme and reformulations of the planetary boundary layer diagnostic, clouds, and radiation have resulted in closer comparisons between the CCM3 and observations. Long-term CERES measurements are needed to validate the models and provide a sound basis for developing new physical parameterizations.

Time Interpolation and Spatial Averaging (TISA) Working Group

Takmeng Wong led the TISA Working Group where the agenda encompassed validation, satellite sampling, temporal interpolation, algorithm development, and Release 2 issues.

Validation

Wong presented the TISA validation plans. Validation is required for LW and SW TOA total-sky and clear-sky fluxes, window radiance, LW surface flux, atmospheric flux, cloud amount (total and levels), cloud particle size, cloud liquid and ice water path, cloud emittance and optical depth (daytime only), and cloud height and thickness. Pre-launch validation involves applying CERES algorithms to ERBE data and comparing the results to "truth" data from other satellite and surface observations. When CERES data are available, qualitative evaluations will be made based on comparisons to previous ERBE data, ERBE wide-field-of-view data (if available), Scanner for Radiation Budget (ScaRaB) data (if available), GOES cloud properties, ARM data, CAGEX, and operational ground station observations. EOS AM results will also be validated by comparison with TRMM data.

Algorithms/Science

Release 1 TISA algorithms have been delivered to the DAAC on schedule. Maria Mitchum summarized the outstanding TISA Release 2 issues: (1) improve ERBE-like clear-sky/cloudy-sky threshold, (2) derive technique for normalizing the geostationary cloud products to CERES observations, (3) use local time vs. GMT in binning the data, (4) derive technique for calculating vertically integrated cloud properties, (5) incorporate a surface emittance map, (6) evaluate image enhancement techniques for spatially averaging flux and cloud data, (7) explore RAP scanner sampling errors, and (8) develop a technique to incorporate ISCCP B1 rather than B3 data.

Wong used Minnis' Layer Bispectral Threshold Method (LBTM) "truth" cloud dataset over the TOGA region in the western Pacific Ocean for December 1992 to determine temporal interpolation errors for cloud amount and visible optical depth. Results showed that temporal interpolation errors are large for the CERES single satellite product and decrease as the number of satellites increases. The use of cloud products from geostationary satellites reduces CERES temporal interpolation errors for cloud amount and optical depth by up to 50%. He concluded that geostationary cloud data should be incorporated into the CERES cloud temporal interpolation scheme. The improved CERES cloud and TOA flux data should reduce errors in both the surface and atmospheric radiative flux products.

Dave Young discussed options for acquiring geostationary data. He showed data provided by Mathew Schwaller (GSFC) on spatial and temporal resolution, data volume, contents, and expected time delay for ISCCP data products. A tentative decision was made to use ISCCP B1 data for CERES temporal interpolation. A sample B1 dataset has been acquired for testing. Young also discussed the problem of clear-sky data gaps. For ERBE, 10-50% of land regions lacked monthly mean clear-sky data. He concluded that the primary cause of the data gaps is inadequate LW thresholds and proposed development of regional, monthly LW thresholds from ERBE data for use on CERES.

Dave Doelling presented some LW results of ongoing CERES spatial sampling studies. Spatial sampling rms errors for the RAP scanner were about twice that of a crosstrack scanner for all three satellites. A "truth" radiation and cloud data set is being developed using a full month of GOES 8-km, 1-hr data and LBTM clouds for testing interpolation methods and determining spatial sampling errors. This dataset, in conjunction with the CERES Point Spread Function, will provide a tool for estimating crosstrack and RAP scanner sampling errors, evaluating arithmetic and resolution enhancement techniques for spatial averaging of radiation and clouds, e.g., image sharpening, and determining spatial sampling errors for cloud parameters.

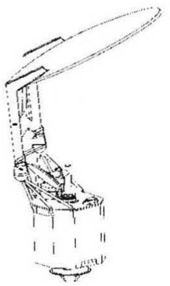
Tropical Rainfall Measuring Mission (TRMM)

The Science Team toured the GSFC Spacecraft Integration Facility to observe the CERES instrument mounted on the TRMM spacecraft. Chris Kummerow, TRMM Deputy Project Scientist, gave an overview of the TRMM mission, spacecraft, and instrument status. While the TRMM precipitation data provide information on latent heating within the tropical atmosphere, CERES provides information on radiative heating. These two components dominate the tropical energy budget. Of particular interest to CERES, the VIRS instrument has overcome problems with the cooling system and is now scheduled for delivery in April for integration on the TRMM spacecraft. There is currently speculation about a TRMM follow-on mission around 2002 in a high-inclination orbit. VIRS has been mentioned as a likely instrument for this mission, but no decision has been made concerning the CERES instrument. King reiterated that CERES measurement of radiative fluxes is a primary research goal of the U.S. Global Change Research Program. The Science Team strongly recommended that a CERES instrument be included on any TRMM follow-on mission. Bruce Wielicki will contact the appropriate scientists in Japan to make the case for CERES.

Meeting Wrap-Up

Validation plans are due by March 31, 1996. The next CERES Science Team meeting is scheduled for September 18-20, 1996 at the Langley Research Center. Major topics will include instrument flight qualification tests, approval of the CERES validation plan, Release 1 algorithm testing, and Release 2 status. ■

Advanced Microwave Scanning Radiometer (AMSR) Science Team Meeting



— **R. Spencer** (roy.spencer@msfc.nasa.gov), Team Leader, NASA Marshall Space Flight Center
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U. of Alabama in Huntsville

The first U.S. EOS PM-1 AMSR Science Team meeting was held on April 23-24, 1996 at Goddard Space Flight Center. The agenda included welcoming remarks from the EOS PM Project Office, status of the hardware, and other team business. In the remaining time, the Team members discussed their roles and responsibilities in producing the standard product algorithms and additional needed validation experiments. It is expected that all of the Team members will have important roles to play in the successful delivery and operation of standard data product software for the PM-1 AMSR. The Team also recognized the need to include their Japanese counterparts in algorithm development or refinement, to the extent possible, given the short lead time before the Algorithm Theoretical Basis Documents (ATBDs) and other documentation are due in late 1996.

A meeting of the newly selected ADEOS-II AMSR Team members will take place in Tokyo in late June. At this meeting, it is hoped that each of the AMSR product types will be represented by visiting U.S. Team members. It is expected that a useful dialog will be initiated with the Japanese on algorithm issues related to both ADEOS-II and the PM-1 AMSR instruments. Of particular concern to the U.S. Team is the desire to receive ADEOS-II AMSR data soon after launch in mid-1999.

Marty Donohoe, EOS PM Project Manager, welcomed the Team to Goddard and gave the status of the common spacecraft contract: the date of the contract restart was April 15, and the redesign of AMSR (to fit in the PM-1 launch shroud) is complete. Pete Pecori, PM-1 Instrument Manager, and Bernie Graf, AMSR Project Manager, have worked on this interface and are satisfied that the latest proposed design from the Mitsubishi Electronic Company (MELCO, the AMSR instrument contractor) will be successful.

Michael King, EOS Senior Project Scientist, discussed briefly the PM-1 mission status and then concentrated on the Team Member and Team Leader responsibilities. He then reviewed the ATBD contents and schedules. The plan is for our ATBDs to be in to the Project Science Office (PSO) by November 15, 1996, to be reviewed, and the peer review presentation to take place in early 1997.

Frank Wentz will have the lead role for the development and application of a spatial resampling scheme for matching the high-resolution, high-frequency channels of the AMSR to the low-frequency, low-resolution channels. This processing is necessary for most algorithms that require multiple-frequency observations. Much of this development work has already been accomplished, and was presented to the Team at the meeting. One of the major findings of this work was that a regridding of all of the data to a raster-scan geometry or latitude/longitude grid is counter-productive since it smoothes out some of the spatial information content of the raw data.

Roy Spencer, AMSR Science Team Leader, presented the ground rules for an acceptable standard data product algorithm. The Team agreed that these standards should include (but not necessarily be limited to):

- ◊ low cross-talk with other parameters, e.g., temperature;
- ◊ a high signal-to-noise, relatively "bullet-proof" design;
- ◊ be only as complex as necessary (simplicity preferred);
- ◊ physically-based, where possible; and
- ◊ include heritage (publications and research community acceptance).

He also presented a proposed ATBD index, matching

Team members with algorithms:

PMR-01	Level 1c algorithm	F. Wentz
PMR-02	Ocean Parameter Suite	F. Wentz, T. Wilheit, J. Alishouse
PMR-03	Sea Ice	D. Cavalieri, J. Comiso
PMR-04	Precipitation	R. Adler/C. Kummerow, T. Wilheit, J. Alishouse/R. Ferraro
PMR-05	Land	TBD (Team member to be selected)
PMR-06	Snow	TBD (Team member to be selected)

Following is a summary of the discussions between the algorithm authors:

Ocean Suite of Parameters (integrated water vapor, clouds, surface wind, sea surface temperature)

The lead role for production of the "ocean parameter" suite will be assumed by Frank Wentz, with John Alishouse leading the effort on ground-truth validation data sets, and Tom Wilheit providing a regression-based set of ocean suite retrievals as a validation "sanity check." The physical retrieval of the ocean suite of parameters from the DMSP SSM/I has been very successful and has demonstrated the superiority of physically-based algorithms where the physics of the various retrieved parameters are well defined. The use of routinely gathered meteorological data for validation will be critical to validation of the ocean parameters, with buoy and radiosonde data being the most useful types of data. These data will be gathered by NOAA. Tom Wilheit's regression-based ocean retrievals will be tested after launch of ADEOS-II AMSR for the possibility of using them as a first guess in the physical retrieval method.

Sea Ice

Agreement could not be reached at the meeting concerning which algorithm should be used for sea ice parameter retrieval. As a result, Don Cavalieri and Joey Comiso agreed to hold a workshop in late July with the goal of having the sea ice community form a consensus about which technique should be implemented as a standard product. The ground rules for standard products (discussed above) will provide the primary basis for selection. Both of these Team members are aware that this will reduce the time available to meet the November due date for the ATBDs, and they will plan their schedules accordingly.

Precipitation

The precipitation retrieval procedures will build upon the Tropical Rainfall Measuring Mission (TRMM) experience. A cloud-model and radiative-transfer-model-based physical retrieval algorithm from GSFC (Chris Kummerow/Bob Adler) will provide Level 2 oceanic rain estimates, while a NOAA/NESDIS (Grody/Ferraro/Alishouse) empirical algorithm will provide rain estimates over land. The Level 2 oceanic rain rates will be input into Tom Wilheit's probability distribution function (pdf) technique to provide Level 3 (monthly gridpoint) rainfall estimates. As a separate validation procedure, Tom Wilheit will separately retrieve Level 2 rain rates and, through his pdf procedure, provide monthly rain rates that can be compared to the GSFC rain totals.

It was also tentatively agreed to retrieve the relative proportions of convective versus stratiform precipitation. This is consistent with the basic information content of the low-frequency observations (rain below the freezing level) and high-frequency observations (large ice condensate above the freezing level).

Land Surface Parameters and Soil Moisture

This Team member has not yet been selected.

Snow Cover Parameters

This Team member has not yet been selected.

Dawn Conway, the Team Leader's software engineer, presented briefly some of the EOS standards that will have to be followed in the coding of the algorithms.

The last topic for discussion was a Validation plan for the AMSR standard products. This plan will rely heavily on routinely gathered meteorological data. These data have proved valuable in the past for validation and calibration of SSM/I algorithms. The accompanying table, assembled during our Team meeting, illustrates the types of data that will be needed for the validation efforts after launch. In Table 1, "Expected Data" refers to those routinely gathered data that will only need to be coordinated and made available to specific team members, and includes data from other satellite instruments as well, e.g., AVHRR sea surface temperatures. "Needed Data" refers primarily to aircraft deployments of existing radiometer packages.

The next Team meeting is planned for June 12, 1996 at Goddard Space Flight Center, a day before the PM-1 platform science working group meeting.

Table 1. *PM-1 AMSR Validation/Field Experiments*

Ocean Suite
- Expected Data: raobs (water vapor, winds,...); buoys (SST, winds,...); AVHRR (SST); PM-1 MODIS (SST)
- Needed Data: aircraft (6.9 and 10.7 GHz wind direction, 6.9 GHz for SST...difficult to do with an aircraft instrument); NOAA Stepped-Frequency Microwave Radiometer (SFMR)

Precipitation
- Expected Data: radars; rain gauges
- Needed Data: TRMM radars (extend support in time) extratropical experiment (?); aircraft radars (JPL or Japan); GSFC aircraft radiometers; Advanced Microwave Precipitation Radiometer (AMPR) & ER-2 Doppler Radar (EDOP)

Sea Ice
- Expected Data: Landsat; AVHRR; PM-1 MODIS; SAR (special cases)
- Needed Data: aircraft (all channels); Japan AMSR simulator; AMPR; Conically Scanning Two-look Airborne Radiometer (C-STAR); digital camera; GSFC aircraft radiometers

Land/Snow
- Expected Data: surface reports (snow depth, water content)
- Needed Data: MODIS Airborne Simulator (MAS)

■

Second Joint Tropical Rainfall Measuring Mission (TRMM) Science Team Meeting

— **Renny Greenstone** (renny@ltpmail.gsfc.nasa.gov), Hughes STX Corp.

This very fruitful second meeting of the Joint TRMM Science Team (JTST) took place December 13, 14, and 15, 1995 at the Tokai University Center in Honolulu, Hawaii. Joint chairpersons of the meeting were the U.S. Project Scientist for TRMM, Joanne Simpson of the Goddard Space Flight Center (GSFC), and the Japanese Project Scientist for TRMM, Professor Tsuyoshi Nitta of the University of Tokyo.

Wednesday, December 13

Among other leading officials present at the meeting were Yukio Haruyama of the Japanese National Space Development Agency (NASDA) and Toshifumi Sakata of Tokai University (the host institution). (Dr. Sakata chairs Japan's Earth Environment Observation Committee.)

Ramesh Kakar, the TRMM Program Scientist (NASA Headquarters), thanked the Japanese for setting up the meeting, and Cheryl Yuhas (NASA Headquarters) said that the Memorandum of Understanding (MOU) between Japan and the U.S. for the TRMM program had been signed, as of October 20, and the joint program was now official. Kakar then went on to discuss developments regarding the ground-based rain-measuring radar to be installed at Kwajalein as part of the overall ground validation network.

Tom LaVigna, the TRMM Project Manager (GSFC), gave the current status of the TRMM Project. He said that most of the flight hardware has been delivered, and the Project is officially on schedule for an August 1997 launch, although the funding is tight.

LaVigna reviewed several major concerns he had for the TRMM program. Foremost among them was his concern for the consequences of a potential launch delay. He showed the effects of varying from the originally planned August 1997 date to possible delayed dates of November 1997 or February 1998. The shift to November is likely because of NASDA's need to accommodate the COMETS mission. The further delay until February would be caused by the limited launch periods that have been agreed to by the Japanese fishermen's union.

The delays have consequences that are related to the increased solar activity that has been predicted for these future years. With increased activity and, therefore, more atmospheric drag, the rate of fuel expenditure increases. Then the days of marginal mission life decrease substantially, and the required number of orbital maneuvers increases. In view of these troubling predictions, LaVigna has asked NASDA to increase the TRMM mass allocations to preserve mission life.

Seiichi Ueno (NASDA/EORC) reviewed the status of the precipitation radar (PR) instrument, which is being developed by Japan for the TRMM mission. In his review he noted the problem that had been encountered with the failure of some of the low-noise amplifiers. As a result of the failures, the engineering model of the PR is being refurbished and being delivered to GSFC in December 1995 for mechanical integration and the electrical interface test in advance of the delivery of the flight model.

Tom Wilheit (Texas A&M University) gave a presentation on the TRMM Microwave Imager (TMI). He said that the TMI is a very mature instrument that is based on the successful Special Sensor Microwave/Imager (SSM/I) instrument and noted that the flight version has been delivered to GSFC.

Bob Adler (NASA/GSFC) gave a status report on the TRMM Visible Infrared Scanner (VIRS) instrument. VIRS meets all the noise specifications and will serve as a calibrator for data from the geosynchronous satellites. It also will be a valuable contributor to the development of combined instrument data products. Of itself, it might contribute to the detection of biomass burning.

Following the morning break, Yukio Haruyama (NASDA) described the Japanese Earth study program and showed the schedules for various Japanese Earth Observations programs.

At this point Tsuyoshi Nitta gave a presentation on the negative impacts of the possible TRMM launch delays. In this presentation Nitta referred again to the loss of useful mission life that had been brought up by LaVigna. Then he discussed other negative impacts due to loss of overlap with other missions that have already been scheduled.

Nitta described the overall progress being made in the area of Japanese TRMM science activities and followed this with a discussion of the NASDA TRMM Science Program document, which corresponds to the NASA Science Operations Plan (SOP).

As U.S. TRMM Project Scientist, Joanne Simpson (GSFC) described the status of the U.S. TRMM science program. She said that U.S. TRMM science is focused on launch algorithms, validation data, field programs, and the SOP. All "day one" science algorithms have been selected.

TRMM's new approach to ground validation plans is based on the concept that "quality is more important than quantity." It is necessary to work with data from both ground and space. Data from TRMM ground sites are regarded as one of several data sets to determine rainfall amount and radar echo structure. The four primary ground validation sites are Melbourne (Florida), Darwin, Kwajalein, and Houston. Data from these sites will be processed continuously by the TRMM Science Data and Information System (TSDIS), and each site will have a Principal Investigator (PI). Florida and Texas will operate four high-quality radars, monitoring 600 by 600-km areas and developing water budgets.

Special "climate" sites will have PI-operated radars and operate 3-4 months per year. These sites are São Paolo (Brazil), Israel, Thailand, Guam, Hawaii, and Taiwan.

The agreed minimum of field programs calls for one over water and one over land. Cooperation with existing field programs such as LBA [LAMBADA (Large-Scale Atmospheric Moisture Balance using Data Assimilation); BATERISTA (Biosphere-Atmosphere Transfer and Ecological Research *in situ* Studies in the Amazon); AMBIACE (Amazon Biology and Atmospheric Chemistry Experiment)] is particularly desired because of the limited funding for such activities. Kwajalein, as the primary ocean site, will provide crucial observations.

Following a lunch break there was a presentation by Erich Stocker (GSFC) on TSDIS status and science algorithm configuration management; and then Makoto Satake (NASDA/EOC) reported on the development status of the Japanese EOC/TRMM Data Processing System. Seiichi Ueno followed with a discussion of the status of the Japanese Earth Observation Information System (EOIS) Data Analysis System (DAS).

Tsuyoshi Nitta presented a draft version of the Joint TRMM Science Team (JTST) "Top-Level Agreement" for approval by the JTST members. (Copies of the Top-Level Agreement with agreed-upon changes may be obtained from the office of the U.S. TRMM Project Scientist by sending requests to Tricia Gregory: gregory@agnes.gsfc.nasa.gov).

Following the afternoon break, Tom Wilheit reported on TMI progress on the U.S. side. He reported the good news that the physically based algorithms are converging, and that an improved "beam filling" correction scheme has been developed. It has been shown that the beam filling error is directly proportional to the freezing level height.

Eric Smith (Florida State University) gave an update on TRMM "combined algorithms," specifically, PR/TMI combined algorithms. The team has defined three options for PR/TMI combined algorithms: augmented radar (narrow swath); augmented radiometer (wide swath); and tall vector (narrow swath). The first option has been selected for the "day 1" solution, and there have been successful tests of the type 1 approach for typhoon Oliver.

Thursday December 14

The first speaker of the morning was Bob Adler (GSFC) on "TRMM with Other Satellites." The concept is to use TRMM as a "flying rain gauge" to improve the global precipitation index (GPI) derived from the geosynchronous satellite data. Adler noted that this way of combining data overcomes the TRMM limited-sampling problem but has the weakness that TMI does not offer a good contribution over land. Combining TRMM products with other satellite data gives finer resolution; thus 1-degree-by-1-degree and 5-day-resolution data could be available.

Bob Houze (University of Washington) addressed ground validation (GV), discussing the two topics of building up climatology and short-term field programs. He noted that the complex flow of GV activities, starting in December 1994, would be the first example of building a climatological program along with satellite flights on a quasi-operational basis.

The recognized ultimate goal of TRMM is to determine the 4-dimensional heating of the atmosphere. The problem comes down to determining divergence as the indicator of the vertical heating gradient, and aircraft measurements can be used to obtain the divergence profiles.

Tom Wilheit gave an update on the status of *Physical* Validation. Wilheit said that determination of oceanic rainfall is the real *ground* validation problem, but *space* observations over ocean will be at their best because of the ocean's uniform characteristics. He cited the principal results from the GV workshop and said that variability in the vertical structure of the hydrometeors was the principal source of error. He asserted that the quality of the TMI measurements is certain to be better than that of all previous spaceborne microwave radiometer measurements.

Otto Thiele (GSFC) described the U.S. TRMM Global Validation Program (GVP). He showed the TRMM GV sites and the data flow. March 1996 is the date for the start of version 3 GV product processing, with Brazil serving as a prototype facility. In the period January to August 1997, GV products are to be produced "commensurate with the planned TRMM overpass schedule."

Kenji Nakamura (Nagoya University) spoke on Japanese calibration/validation activities. Routine data will come from Japan Meteorological Agency radars and the Automated Meteorological Data Acquisition System (AMeDAS). Overpass data will be supplied by the Communications Research Laboratory (CRL) and middle and upper atmosphere (MU) radars. Campaign experiments are planned for the Kanto plain, the MU radar site, and the Ishigakijima Island. Houze said that data from the 14-scan radar on Ishigakijima Island would be good to have as a TRMM direct product.

Krishnamurti (Florida State University) reported for the U.S. TRMM Modeling and Data Analysis Group, stressing the particular value of the GSFC Cloud Ensemble Model (GCEM). The GCEM is being used to validate TRMM rainfall derivation algorithms and convective and stratiform rainfall partitioning schemes, using data from other experiments such as TOGA/COARE. As part of the Modeling Group Bill Lau's team is studying the various monsoon-related phenomena. The Florida State University physical initialization studies seem to show that rain *rates* are not as important as rain *locations*.

Tetsuo Nakazawa (MRI) described the activities of the Japanese Modeling and Data Analysis Team. He listed research and application studies, divided into the categories of fundamental and applied: *Fundamental* studies are devoted to the establishment of the space-time characteristics of tropical rainfall; the establishment of the cloud physics of tropical rainfall systems; and the understanding of rainfall systems in the subtropical rainfall zone. *Application* studies include improving the predictability of a forecasting model; improving forecast skills for global environmental variations; and learning how to reduce the potential for disasters.

In the next session, Toshiaki Kozu (CRL) described work that is being done on the cross calibration of the Airborne Rain Mapping Radar (ARMAR) and the CRL Airborne Multiparameter Precipitation Radar (CAMPR).

Following the Thursday lunch break, Tom LaVigna (GSFC) introduced a group presentation on satellite maneuvers and the instrument operations planning and coordination process at Goddard. In his introduction he said that TRMM will have carry-over benefits to other space projects as well because it has led the way in developing spacecraft surfaces that will protect against erosion due to atomic oxygen in the outer atmosphere that will be encountered during TRMM's long stay in relatively low orbit.

Makoto Satake (NASDA/EOC) addressed a number of topics that needed to be discussed or coordinated at the JTST meeting. He particularly mentioned data and algorithm sharing issues. Chris Kummerow (GSFC) addressed strategy and procedures for developing algorithm version upgrades. He said that the remaining problem is how to know whether a new algorithm is better than the previous algorithm.

Friday, December 15

The final session opened with a discussion by Kakar on research announcements. He said that another NASA Research Announcement (NRA) is needed to provide funding for the period after the TRMM launch. A target date for this announcement would be the end of FY 96.

Seiichi Ueno led the final summary/wrap-up review. The first order of business was a review of a previously drafted statement on launch delays. Next, Ueno presented a chart showing the schedule of the second Japan Research Announcement (JRA), which generally parallels the schedule of the U.S. NRA. Modifications to the "Joint TRMM Science Team Top-Level Agreement" were also reviewed.

As the meeting came to an end, Kakar thanked the Japanese side for agreeing to host the very rewarding meeting in Hawaii. Simpson voiced her appreciation as well. Haruyama also thanked all for coming and for having the meeting in Hawaii. Finally, Nitta expressed his thanks to all and said that he was glad that an agreement had been reached on algorithm development. ■

Science Working Group for the AM Platform (SWAMP) meeting

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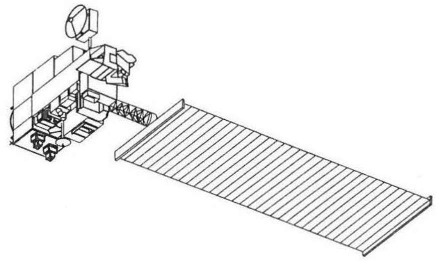

The Science Working Group for the AM Platform (SWAMP) met at the Lockheed Martin Astro Space facility in Valley Forge, Pennsylvania, on March 21 and 22, 1996. There was full attendance by all the EOS AM-1 Team leaders, by most of the software leads, and by several EOS AM-1 Project and ESDIS staff members.

Welcome and Project Status

After a brief welcome speech by Mike Kavka, the EOS AM-1 Project Manager at Lockheed Martin, Chris Scolese discussed the status of the Project: CERES has been integrated onto the TRMM spacecraft; all AM-1 instruments are in fabrication; the spacecraft flight components are in testing; and the Project is working on a three-month advance on spacecraft delivery.

Digital Elevation Model (DEM)

Martha Maiden (NASA Headquarters) is funding the DEM development and Thomas Logan (JPL) will oversee the work. A design study has been initiated and an implementation plan will be out soon. Specialists from JPL and EDC will lead the technical work and the assembly of the DEMs, while ESDIS will arrange for the toolkits to allow teams to access the data. The parties will keep the SWAMP informed of their progress and of any options that may arise.

Land-Sea Masks

Robert Wolfe discussed the need for land-sea masks for model products, and identified them as a desired layer for DEMs. Masks are needed for land, oceans, lakes, and rivers. Equal-angle grids are also needed at 0.25, 0.5, and 1.0 degrees. Robert Wolfe and Bryan Bailey will report at the next microSWAMP on who is to prepare the grids and on the resources required.

SWAMP Position on Recompetition for the Data System

Piers Sellers reiterated the SWAMP view that recompeting products in the EOS AM-1 timeframe would not save money, and would increase risk for EOS AM-1 (as discussed in the SWAMP letter to Dr. Kennel dated November 1995).

This was followed by a review of the letter sent from the Project Science Office to the SWAMP (and of the responses from Team members to the letter) setting out a strategy for deciding which products to offer for recompetition. A small working group was formed to prepare a new letter on the topic, to be signed by all Team leaders and by the Project Science Office.

Calibration

Jim Butler reviewed recent progress with instrument calibration work, and discussed lunar calibration. Lunar/deep space maneuvers are desired by the MODIS, CERES, ASTER, and MISR Teams; such maneuvers are not needed (but they are not feared either) by the MOPITT Team.

The current plan is for GSFC to write the flight software needed to implement the maneuvers. The spacecraft should be capable of performing the maneuvers within 6 months after launch.

X-Band Update

Paul Westmeyer discussed the fact that if X-Band were to be used to download science data, there would be a black-out for direct broadcast north of 60 degrees North latitude.

ASTER Ground Track

Ed Chang discussed the request from the Japanese ASTER ground data system (GDS) for ground track margins to be reduced from ±20 km to ±2.5 km to facilitate ASTER operations. If this were done, orbit adjust maneuvers (using propellant) would increase in frequency from once every 43 days to once every 14 days (or possibly more often). There was opposition to doing this from other instrument teams.

At the next microSWAMP, the ASTER GDS Team will present the science justification for the tighter ground track requirements, and Ed Chang will discuss the likely frequency of maneuvers as a function of ground track requirements.

ASTER Tilting On Day-Side

Ed Chang also discussed the jitter analysis, indicating that ASTER tilts on the day-side will stay within margins, and will not perturb other instruments. All agreed that we should assess the real impact of day-side tilts in flight before committing to them as a routine, long-term practice.

Data System Working Group

Skip Reber reported that the Data System Working Group (DSWG) has worked hard in response to SWAMP concerns raised in November 1995. Those issues included HDF, browse, metadata, ancillary data, and QA. A high-level one-on-one meeting will be needed to resolve some of these issues. The next DSWG meeting is planned for May 1996.

EOS AM-1 Science Software Review (SSR) Summary

Francesco Bordi summarized the science software reviews that were held the two days preceding the SWAMP:

- ◊ beta deliveries were a very useful experience for everyone;
- ◊ remote testing, plus early access to the DAACs are important; recompetition is a concern for all teams;
- ◊ there has been concern that release B purchases would result in a large software modification burden for the teams; and
- ◊ there has been some schedule erosion in some teams for Version 1.0.

Data Assimilation Office

Jim Stobie reported on his work on swath data products from the Data Assimilation Office, and announced that a prototype will be available in June 1996.

Model Grid Products

Piers Sellers reported that the MODIS, MISR, and CERES Teams agree to produce model grid products and will send out a revised letter with specifications for the model grid.

Next SWAMP Meetings

Piers Sellers presented the schedule for the next SWAMP meetings:

There will be a MicroSWAMP meeting at the EOS IWG meeting on May 13, 1996.

There are two options for the next SWAMP/SSR meeting week (and possibly for some ATBD reviews).

Option 1: November 4-8, 1996.
Option 2: November 11-15, 1996. ■

MODIS Cryospheric Products at the NSIDC DAAC

— **Greg Scharfen** (scharfen@kryos.colorado.edu), NSIDC DAAC, University of Colorado, Boulder, CO

The National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC) provides data and information on snow and ice processes, especially interactions among snow, ice, atmosphere, and ocean, in support of research on global change detection and model validation, and provides general data and information services to the cryospheric and polar processes research community. The NSIDC DAAC is an integral part of the multi-agency funded support for snow and ice data management services at NSIDC.

This report gives a brief overview of the planned cryospheric products from the Moderate Resolution Imaging Spectroradiometer (MODIS), how they relate to other products, and how they fit into EOS and NSIDC. These products are being developed by the EOS MODIS Science Team, and will be implemented at the NSIDC DAAC.

Data Sets

Currently, NSIDC produces cryospheric products from Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) data including polar brightness temperature grids, sea ice concentration, and a combined land snow extent (from National Oceanic and Atmospheric Administration/National Environmental Satellite Data and Information Service [NOAA/NESDIS] weekly charts) and polar sea ice from SSM/I. Non-satellite data, such as meteorological fields, station data, and buoy measurements, are archived for comparison to satellite information and for input to sea ice and climate models. The NSIDC DAAC has supported the development of products to monitor ice surface temperature and ice motion by providing access to bi-polar subsets of Advanced Very High Resolution Radiometer (AVHRR) and TIROS Operational Vertical Sounder (TOVS) satellite data since 1992/93. Satellite altimetry data are being archived and distributed to support ice-sheet topography studies.

The Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS will be launched as part of the science payload on the first EOS platform (AM-1) in 1998. MODIS represents a technological improvement over the AVHRR sensors, which are the mainstay of the NOAA Polar Orbiting satellite program. MODIS will have a viewing swath width of 2300 km and will collect data in 36 spectral bands from 0.4-14 µm, with a spatial resolution ranging from 250 to 1000 m. The AM-1 satellite will be in a sun-synchronous, near-polar orbit (at about 705 km altitude) with a descending node at about 10:30 a.m. local time. Follow-on satellites with MODIS-type instruments will be in similar orbits with either the same approximate schedule or a 1:30 p.m. local time ascending node. This configuration results in global coverage every one to two days by each satellite, although the polar regions will be covered more frequently because of the overlap between satellite passes at the poles.

MODIS data will be calibrated during normal inflight operations. Calibration will include radiometric checks and spectral band registration checks.

Development of Methods for Mapping Snow Cover from MODIS Radiances

Snow cover is an important variable for global climate monitoring and change detection (Barry *et al.* 1995). Owing to its high albedo and large spatial variability, snow cover is a primary factor controlling the amount of solar energy absorbed at the surface. Changes in the extent of snow cover have a direct effect on the radiation budget. Snow cover also has significant effects on the seasonal temperature cycle due to its high latent heat of fusion. In many areas of the world, snow cover represents an important resource in terms of water supply and hydroelectric power. Links between snow cover extent and atmospheric circulation have been demon-

Table 1. V0 data sets currently held or under development at NSIDC

Platform	Instrument or Experiment	Data Set Name	Product Level
Satellites	Multi	Northern Hemisphere Weekly Snow Cover and Sea Ice Extent 1978-	3
ERS-1	SAR	Greenland SAR Base Map	3
Nimbus-7, DMSP	SMMR, SSM/I	Passive Microwave Derived Global Weekly Snow Cover, 1978-	3
in-situ		SCS US Snow Depth and Water Equivalent Climatology	2
NOAA	AVHRR	Ice 5 km Motion Vectors, Ice Surface Temperature, Albedo, Cloud	3
NOAA	AVHRR	AVHRR 1.25 km Ice Motion Vectors, Ice Surface Temperature, Albedo, Cloud Mask	
NOAA	AVHRR	AVHRR GAC 4 km Backup	1A
NOAA	AVHRR	AVHRR Polar 1 km Subset	1A
NOAA	AVHRR	AVHRR 5 km EASE-Gridded Bands and Angles	3
NOAA	AVHRR	AVHRR 1.25 km EASE-Gridded Band 2 and 4	3
NOAA	AVHRR	AVHRR Arctic Leads	3
NOAA	AVHRR	AVHRR Ice Maps	
NOAA	AVHRR	Sea-Ice Motion Products for Modeling and Monitoring	3
DMSP F8	SSM/I	F8 EASE Gridded Daily Brightness Temperatures Global, Northern and Southern Hemisphere	3
DMSP F11	SSM/I	F11 EASE Gridded Daily Brightness Temperatures Global, Northern and Southern Hemisphere	3
In-situ	N/A	Rawinsonde Over Polar Regions (HARA)	1B
Multi	Multi	Russian Digitized Sea Ice Charts (NOAA) (AARI)	3
In-situ	Multi	CEAREX Data Sets	2, 3
DMSP F11	SSM/I	F11 Gridded Brightness Temperatures and Sea Concentrations	3
DMSP	SMMR, SSM/I	Pathfinder SMMR-SSM/I Global Snow Cover 1978-present	3
SEASAT, GEOS, GEOSAT, ERS-1	Altimeter	Ice Sheet Altimetry Data Set	2, 3
Nimbus-5	ESMR	Brightness Temperatures and Sea Ice Concentrations	1B, 2
Multi	Multi	Gridded Sea-Ice Surface Energy Fluxes (POLES)	4
Multi	Multi	Gridded Cloud Cover, Type, Height (POLES)	3
Multi	Multi	Cloud Cover, Type, Height (by Orbit) (POLES)	2
NOAA	AVHRR	Ice Margin Ocean SSTs	2
Radarsat	Radarsat	Radarsat Antarctic Mapping Project (RAMP)	3
DMSP	Multi	Beaufort Arctic Storms Experiment (BASE)	3
Nimbus-7	SMMR	SMMR EASE Gridded Daily Brightness Temperature Global. Northern and Southern Hemisphere	3
Satellites	Multi	Navy-NOAA Weekly Sea Ice Concentration and Extent	3
NOAA	TOVS	TOVS Pathfinder Path-P Data: Polar Subset	2,3
DMSP	SSM/I	Ice Melt Product	3
DMSP F8	SSM/I	F8 Gridded Brightness Temperatures and Sea Ice Concentrations	3
DMSP	SSM/I	Level 2 Sea Ice Concentration (Pathfinder) (MSFC)	2
Nimbus-7	SMMR	Gridded Brightness Temperatures and Sea Ice Concentrations	3
Nimbus-7	SMMR	Nimbus-7 SMMR Derived Global Monthly Snow Cover and Snow Depth 1978-1987 (Chang)	3
In-situ	N/A	Arctic and Southern Ocean Sea Ice Concentrations (Walsh) (NOAA)	3
In-situ	Multi	Historical Soviet Daily Snow Depth 1881-1985	2
In-situ	N/A	Arctic Water Vapor Characteristics from Rawindsone, Ice Station, and Other Data	3
In-situ	N/A	International Arctic Buoy Program Pressure, Temperature, Position and Ice Velocity Data	1B, 2, 3

strated (Walsh *et al.* 1985), and the extent of snow cover has been found to be inversely related to hemispheric surface air temperature (Robinson and Dewey 1990).

The MODIS snow cover products are being developed by the MODIS Science Team (Hall *et al.* 1995). This work follows on a history of monitoring large-scale Northern Hemisphere snow cover extent from visible and infrared satellite sensors, especially those aboard the NOAA polar orbiting satellites (Matson *et al.* 1986). Northern Hemisphere snow cover has been mapped by NOAA/NESDIS analysts from the Very High Resolution Radiometer (VHRR) and AVHRR sensors on these satellites since 1966. The record of data has been scrutinized and found to be most reliable from 1972 onwards (Robinson *et al.* 1993). Analyses of the record by Robinson and others show mean annual snow-covered area for the Northern Hemisphere to be 25.4 million square km. While this record is short, and includes much interannual and regional variability, a decrease in total snow-covered area after about the mid-1980s is readily apparent (Figure 1, Robinson, pers. comm., unpublished 1996). It is not known whether this is a short-term anomaly or part of a longer-term trend.

In addition to the spatial-coverage similarities of MODIS to AVHRR, it has some similar spectral characteristics to Landsat TM data. Much of the development work for MODIS algorithms has utilized the similar spectral bands of Landsat TM

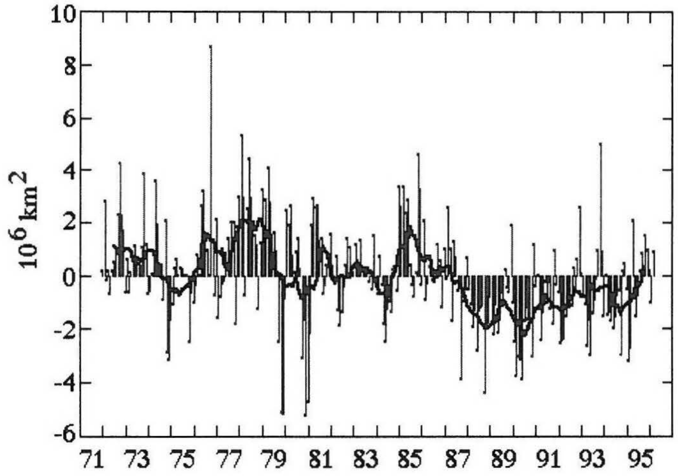

Figure 1. *Monthly anomalies of snow extent over Northern Hemisphere continents (including Greenland), Jan. 1972 - Mar. 1996. Also shown are 12-month running means (plotted on 7th month of interval).*

data. The MODIS Snow Cover Mapping algorithm (SNOMAP) is designed to utilize the reflectance characteristics in the visible and near-infrared regions of the electromagnetic spectrum. Wavelength-center locations and spatial resolution of MODIS bands that have corresponding TM coverage are given in Table 2 (Riggs *et al.* 1994). By utilizing the narrow spectral bands of these sensors, the SNOMAP algorithm is designed to identify snow cover routinely and to discriminate between snow and other features.

SNOMAP has two criteria tests that were developed with TM data and will be applied to the MODIS data (Riggs *et al.* 1994). Digital numbers acquired by the sensor are converted to reflectances using solar zenith angle corrections. A key characteristic of snow is that its reflectivity is high in the visible part of the spectrum and low in the near-infrared at about 1.6 µm (O'Brien and Munis 1975). The reflectivity of clouds remains high in both the visible and near-infrared regions. These features are accounted for in the calculation of the Normalized Difference Snow Index (NDSI), expressed for TM data as: NDSI = (TM 2 [0.56 µm] - TM 5 [1.65 µm])/(TM 2 + TM 5) after Dozier (1989). A NDSI value of 0.4 is used as the threshold for snow. This technique can be used to classify pixels as snow vs. other bright features such as clouds. A second threshold test is applied to the TM band 4 data to distinguish between snow and water. A land-water mask and a cloud mask derived from MODIS data are being integrated into SNOMAP. Use of the cloud mask is expected to improve the ability to discriminate between thin clouds and snow. Errors with this technique are minimal and are usually due to pixels containing cirrus clouds or bright surface features misidentified as snow. The snow cover algorithm will be updated with additional tests using data from the MODIS Airborne Simulator (MAS) that has many of the same spectral characteristics as the MODIS sensor. In addition, the algorithm may be modified after launch of the AM-1 platform to incorporate other tests and possibly other MODIS bands (Riggs et al. 1994).

Development of Methods for Mapping Sea Ice from MODIS

Sea ice is an important variable affecting the energy balance of the polar regions. Sea ice inhibits the exchange of heat and moisture between the atmosphere and ocean, and dramatically increases the albedo of the polar oceans. In the southern ocean the annual cycle of sea growth and decay is very large, ranging from a maximum extent of 20 X 10^6 square kilometers in September to its minimum area of approximately 4 X 10^6 square kilometers in February (Zwally *et al.* 1983).

Table 2. *Corresponding MODIS and TM wavelengths (bands).*

MODIS Band	Spatial Resolution (m)	Center Wavelength (µm)	Corresponding TM Band
1	250	0.645	3
2	250	0.858	4
3	500	0.469	1
4	500	0.555	2
6	500	1.640	5
7	500	2.130	7
13	1000	0.667	3
14	1000	0.678	3
16	1000	0.869	4
31	1000	11.030	6

During freezeup, large quantities of salt are ejected, altering the density structure of the water column.

Sea ice has been monitored by satellites using visible and infrared sensors since the early 1970s. Data from the AVHRR sensor and its predecessors, along with ship and aircraft observations, have been the basis of operational ice mapping efforts at the National Ice Center in Suitland, Maryland, and the Atmospheric Environment Service Ice Branch in Ottawa, Ontario, since the 1970s. These data provide the basis for daily, weekly, and monthly charts showing ice margins, large fractures and leads, and categories of ice concentration. They are used extensively by ships operating in ice-infested waters. Limitations include persistent cloud cover and darkness during much of the year.

In 1972, passive microwave satellite data became available for mapping sea ice extent and concentration. Data from the ESMR, SMMR, and SSM/I passive microwave satellite sensors have a coarser resolution than the visible and infrared data, but have the advantages of being useful year round and with only minimal interference by atmospheric moisture, including cloud cover. These data are available on CD-ROM from NSIDC.

These two approaches for monitoring sea ice with remote sensing data are complementary. The traditional visible and infrared analyses offer greater detail, while the microwave data offer dependability under varying environmental conditions. MODIS data for sea ice analyses will offer an improvement over the traditional analyses in terms of spatial and spectral resolution, but they will still be limited by cloud cover.

The MODIS ice algorithm uses the same tests as the SNOMAP algorithm (Riggs *et al.* 1994). Significant reflectance differences between open water and most ice types allow for detection of ice using the same algorithm. Tests with TM data have shown the algorithm to be acceptable, except for detecting thin ice. Investigation of additional tests to improve the analyses is continuing.

The sea ice product being developed by the MODIS Science Team is sea ice extent on a daily basis, and composited to a weekly or ten-day maximum extent. Additional products, including sea ice albedo, ice surface temperature, and ice motion may be developed after the launch of the AM-1 satellite.

The MODIS Snow and Ice Workshop

In September 1995, a workshop was held at NASA's Goddard Space Flight Center to discuss the MODIS snow and ice products (Hall 1995). Invited participants gave presentations on current snow and ice mapping systems using remote sensing data. Participants were asked to evaluate the products and make recommendations to improve their utility.

For the MODIS snow products, it was recommended that the resolution be improved from 1000 m to 500 m. For the lake ice product, it was also recommended that the resolution be improved to 500 m. For both the snow and ice products it was felt that the compositing period should be specified by the user.

The participants recognized that there was a need for a sea ice product based on optical wavelengths, but felt that it would be more useful if it included other ice information, such as concentration, ice type, ice surface temperature and albedo, if possible. The participants also recognized the utility of current passive microwave products and the planned active microwave products from RADARSAT.

The utility of gridding and projection schemes was also discussed. It was recommended that the products be available in a polar grid as well as the standard EOS grid (an adaptation of the International Satellite Cloud Climatology Project grid).

Operational users expressed interest in receiving the data as soon as possible (within 48 hours) for incorporation into near-real-time forecasts.

To the degree possible, these changes are being included in revisions to the MODIS snow and ice product algorithms (D. Hall, pers. comm.). The Science Team is continuing to investigate ways to provide other sea ice parameters. Candidate algorithms are being investigated, and new techniques such as spectral mixture modeling may be incorporated in the post-launch timeframe.

Concluding Remarks

The EOS MODIS Science Team is developing snow and ice products to be implemented at the time of the launch of the first EOS mission on the AM-1 platform in 1998. MODIS products will be distributed via EOSDIS from the GSFC, EDC, and NSIDC DAACs. Present plans call for NSIDC to archive and distribute the MODIS snow and ice products. These products will utilize the improved spatial and spectral resolution of MODIS over current visible and infrared sensors and offer an improvement over currently available similar products. They will complement the related microwave and radar data to generate "all weather" snow and ice products. Daily maps of global snow cover and sea ice and lake ice extent will be produced and archived. In addition, the MODIS data offer the potential for the development of other cryospheric products. More information on these products may be found at the MODIS Home Page (http://ltpwww.gsfc.nasa.gov/MODIS/MODIS.html), or the Algorithm Theoretical Basis Document Home Page (http://spso.gsfc.nasa.gov/atbd/pg1.html).

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The National Research Council's Space Studies Board report titled "Earth Observations from Space: History, Promise, and Reality" as prepared by the Board's Committee on Earth Studies (CES) under the direction of John McElroy, Dean of Engineering at the University of Texas, Arlington, is now available. Copies may be ordered free of charge from Carmela Chamberlain, Space Studies Board, HA584, National Research Council, 2101 Constitution Avenue, Washington, DC 20418, or via e-mail at cchamber@nas.edu.

Calibration in the EOS Project
Part 2: Implementation

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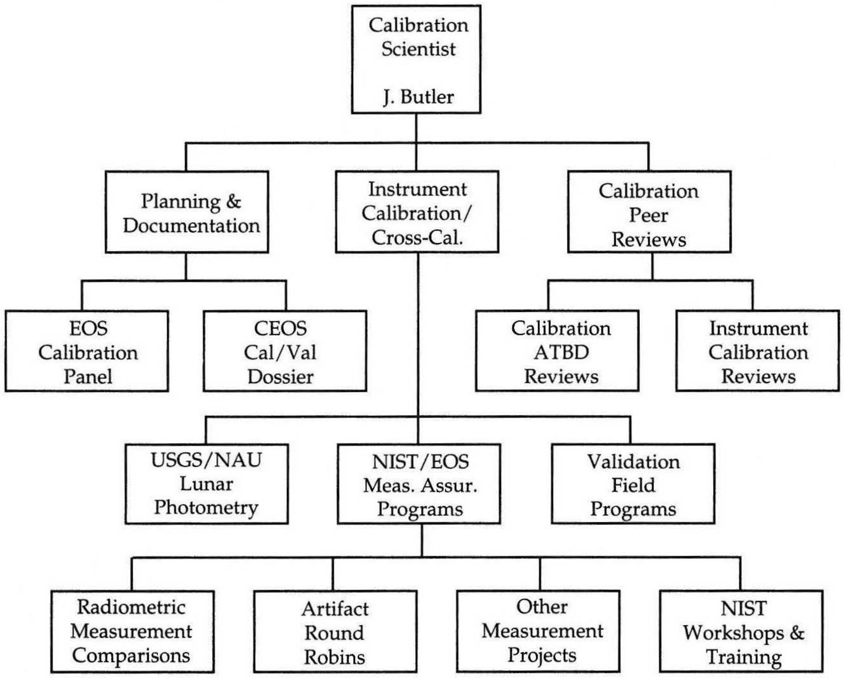
Introduction

To fulfill its mission, EOS must produce accurate, precise, and consistent long-time series measurement data from multiple instruments on multiple platforms. The correct interpretation of these long-time series data requires the ability to differentiate actual changes in the remotely sensed Earth from changes in the measuring instrumentation. This can only be accomplished by (1) calibrating all instruments against a set of recognized physical standards, (2) carefully characterizing the instruments' performances at the system level, (3) adhering to good measurement practices and established protocols, (4) intercomparing instrument measurements, and (5) establishing traceability to the physical standards via an impartial standards organization.

Implementation of the EOS Calibration Program



This article constitutes Part 2 of a two-part article describing the overall organization and implementation of a calibration program in the EOS Project based on requirements initially established in 1989 (EOS Project Requirements Level 1A, 1989). Part 1 (Butler and Johnson 1996) described the organization of the EOS Calibration Program, its position in the EOS Project Science Office's Panel for Data Quality, and the implementation of the program with respect to planning, documentation and peer reviews. This article completes the description of the implementation of the program by outlining the EOS approaches to pre-flight and on-orbit calibration.

Key to these approaches are the measurement assurance programs (MAPs) in pre-flight and on-orbit calibration supported by the National Institute of Standards and Technology (NIST), the lunar radiometric measurement program for on-orbit calibration being conducted by the United States Geological Survey (USGS) and Northern Arizona University (NAU), and the execution of field programs to validate EOS instrumental Level 1B data. Where appropriate, examples of on-going calibration programs relevant to the EOS AM-1 instruments are provided.

Implementation of the EOS Calibration Program

Figure 1 illustrates the implementation of the EOS Calibration Program and shows the positions of instrument calibration and cross-calibration in the overall implementation scheme (the term cross-calibration is defined below). Pre-flight calibration and pre-flight and on-orbit cross-calibration of EOS instruments are critical to the success of the EOS mission. Extension of these calibration and cross-calibration activities to field instruments involved in the Level 1B data validation of the EOS instruments ultimately improves the validity and reliability of the EOS instruments Level 1B data. As seen in Figure 1, EOS calibration and cross-calibration is a multifaceted program, incorporating the NIST MAPs, the USGS/NAU lunar radiometric measurement program, and Level 1B data validation field programs.

NIST Measurement Assurance Programs

A MAP is any group of activities designed to critically evaluate the accuracy of a group of measurements. When implemented by NIST, it is a quality control procedure designed to calibrate a customer's entire measurement system (Simmons 1991) and establish traceability to NIST. A key part of the EOS Calibration Program are the MAPs operated by the EOS Project Science Office with support from NIST. In addition to evaluation of the pre-flight and on-orbit instrument calibration activities, the MAPs include:

◊ comparing the results of simultaneous measurements of similar physical quantities from instruments on the same satellite or instruments at the same field site, intercalibrated with a common radiometric standard, i.e., instrument cross-calibration;

◊ estimating the accuracy of the EOS results by comparison with results from airborne, shipborne, or land-based sensors, again in the case where the field and space sensors are designed to estimate similar physical quantities, i.e., Level 1 data product validation; and

◊ evaluating all measurements arising from sequential EOS platforms, other space-based sensors, and the aforementioned field sensors in order to assess the long-term stability, reliability, and accuracy of the estimates of physical quantities resulting from scientific studies of the Earth's environment, i.e., long-time series data continuity/reliability.

As indicated in Figure 1, the components of the MAPs include the following: radiometric measurement programs, artifact round-robins, other measurement comparisons/services, and intercomparisons, workshops, and training. These are examined below.

Radiometric Measurement Programs

In the pre-flight timeframe, EOS instrument calibration facilities use dedicated, large-area, calibrated sources, i.e., integrating spheres, blackbodies, etc., to determine the radiometric response of instruments operating at optical wavelengths, i.e., ultraviolet to thermal infrared. With the EOS instruments acting as transfer radiometers, these well-characterized, large-area sources are usually used to establish the radiometric scales of any on-board radiometric sources. It is extremely important that the calibration of the laboratory standard sources be consistent between the EOS instrument calibration facilities and accurate with respect to System International (SI) units.

The objective of the radiometric measurement programs is the pre-flight verification of the independent radiometric scales assigned to the sources used in the actual calibration of the EOS instruments. These measurements are usually made at the EOS instrument calibration facilities. The approach is to use stable, portable, well-characterized radiometers traceable to a national standards laboratory to measure the EOS calibration sources. NIST is in the process of designing, building, characterizing, and deploying a set of radiometers that will be used to verify the spectral radiance of these EOS instrument calibration sources. Three radiometers are planned: the EOS Visible Transfer Radiometer (VXR), a six-channel filter radiometer based on the Sea-Viewing Wide Field-of-view Sensor (SeaWiFS) Transfer Radiometer (SXR) (Johnson et al. 1996a), the EOS Shortwave Infrared Transfer Radiometer (SWIXR), a modification of the EOS VXR for the shortwave infrared region, and the EOS TXR, a two-channel cryogenic filter radiometer that can be operated in vacuum or ambient conditions (Rice and Johnson 1996). These radiometers may be deployed with small, stable sources in order to monitor their performance. In addition to verifying the spectral radiance of critical radiometric sources, it is anticipated that these radiometers will be used to perform a number of other functions, including use in validation field programs and measurement technique comparisons. These specific applications are discussed below in the sections entitled Validation Field Programs and NIST Intercomparisons, Workshops, and Training. In fiscal year 1996, NIST will deliver to the EOS Project Science Office the VXR, the engineering plan for the SWIXR, and test data on the TXR prototype.

The radiometric measurement programs have begun. The initial deployment was held at NEC in Yokohama, Japan, in February 1995. During that activity, the SXR, operating in the visible and near-infrared wavelength regions, viewed the integrating spheres used to calibrate the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Ocean Color and Temperature Scanner (OCTS). In addition to the SXR, radiometers from the National Research Laboratory of Japan (NRLM) (Sakuma et al. 1994), the University of Arizona Optical Sciences Center (Biggar and Slater 1993), and a scanning spectroradiometer from NASA Goddard Space Flight Center (Johnson et al. 1996a) also viewed the spheres. Preliminary results indicate an agreement between these measurements of better than 3% for three radiance levels of the ASTER sphere (compared to program requirements of 4%) and four radiance levels of the OCTS sphere (Sakuma et al. 1996, Johnson et al. 1996b). The next measurements are being planned for August 1996, during which time the radiometric scales for the integrating spheres used to calibrate the Moderate Resolution Imaging Spectroradiometer (MODIS), Enhanced Thematic Mapper Plus (ETM+), and the Multi-angle Imaging Spectroradiometer (MISR) will be verified.

These radiometric measurements at instrument calibration facilities using the EOS/NIST radiometers will be performed throughout the entire EOS mission lifetime. Only by performing comprehensive and thorough comparison measurements is it possible for the EOS program to generate long-term, continuous, consistent data that can be confidently subjected to critical evaluation. The practical difficulties of designing and deploying a common, stable, radiometric source deployed at the platform integration facility and viewed by the integrated EOS instruments led to the transfer radiometer approach described above (Minutes of the Sixth General Meeting of the EOS IWG Calibration Panel 1993). Instrument teams are encouraged to bring sources and equipment to the platform integration facility for purposes of performing bench acceptance testing and ensuring that instrument calibration has not changed. The nature of the sources, accompanying equipment, and planned tests are communicated by each instrument team to the EOS Project and the platform integrator well in advance of instrument shipment and platform integration.

Artifact Round-robins

A second activity performed by NIST in support of the EOS Calibration Program is to circulate samples for measurement at selected laboratories. For example, visible, near infrared, and shortwave infrared EOS instruments require an accurate determination of the Bidirectional Reflectance Distribution Function (BRDF) of on-board and laboratory diffuse plaques. Many remote sensing instruments and calibration facilities use diffuse plaques to:

- ◊ establish a source of known spectral radiance using a NIST-traceable standard irradiance lamp (for radiometer calibrations);
- ◊ provide a known value of directional reflectance (for *in situ* reflectance measurements); and
- ◊ provide a stable source of spectral radiance on-orbit using the sun as the source (for on-orbit calibration).

In order to address the scientific goals of the EOS program, measurements of BRDF at state-of-the-art accuracies are required. The simplest way to assess the quality of BRDF measurements is to ask a number of EOS instrument calibration and metrology laboratories to measure the same samples. This EOS-sponsored BRDF round-robin is underway, with the Spectral Trifunction Automated Reference Reflectometer (STARR) facility at NIST serving as the hub in the measurement program (Proctor and Barnes 1996). Other participating laboratories include the University of Arizona Optical Sciences Center, Rochester Institute of Technology, GSFC, Hughes Santa Barbara Remote Sensing (Hughes SBRS), and the Jet Propulsion Laboratory (JPL). Four samples will be measured, consisting of laboratory grade Spectralon™ from Labsphere, Inc.[†], pressed polytetrafluoroethylene (PTFE), baked PTFE, and diffuse aluminum from Ball Aerospace. The PTFE samples will be provided by NIST.

Other Measurement Comparisons/Services

Additional candidate round-robin programs may be identified by members of the EOS Calibration community, presented to the community at EOS Calibration Panel meetings, and brought to the attention of the EOS Calibration Scientist in the form of a well-conceived test plan. For example, round-robin programs for dimensional metrology, e.g., aperture area, and spectrophotometry, e.g., filter transmittance are also possible. NIST is available as the hub, since facilities exist for making accurate measurements of the optical area of apertures (Fowler and Dezi 1995) and regular spectral transmittance measurements on room temperature (Mielenz 1973) and cryogenic filters (Datla, pers. comm.) As with the BRDF round robin, these activities will serve to corroborate the measurement practices, instrumentation, and capability of EOS-related efforts at the various laboratories and commercial facilities; in general they will not be simultaneous with calibration and characterization of flight hardware.

NIST Intercomparisons, Workshops, and Training

For the past four years, NIST has participated in intercomparisons in support of terrestrial ultraviolet (UV) spectral irradiance and ocean color science. The valuable experience gained in these activities will be applied to EOS. The 1994 UV Interagency Intercomparison, led by NIST and the National Oceanic and Atmospheric Administration (NOAA), emphasized instrument characterization, *in situ* interinstrument calibration, and sun-synchronous measurements (Thompson et al. 1996). The program was repeated in 1995 and is scheduled for a third implementation in June of 1996. The ocean color work has been led by the Calibration and Validation Program of the SeaWiFS Project Science Office at GSFC (McClain et al. 1992). Beginning in 1992, based on protocols developed in 1990 by the science community (Mueller and Austin 1992), a series of SeaWiFS Intercalibration Round Robin Experiments (SIRREXs) have been held annually, with NIST participation. The Fourth SIRREX emphasized training and workshops (Johnson et al. 1996a), while the Fifth, scheduled for July 1996, will concentrate on in-water spectral radiance and irradiance measurements, field reflectance measurements, and methods to realize spectral radiance scales for calibration of field radiometers. A general result of the UV intercomparisons and the SIRREXs is that radiometric instruments often suffer from insufficient characterization, inadequate design or improper use when evaluated with respect to the uncertainties required by the underlying science program. Attention to these areas resulted in improved results, a better-educated community, and specific radiometric artifacts for transfer of NIST scales to the science community (Johnson et al. 1996a).

These activities will be extended to the EOS community. Over the life of the EOS mission, the performance of the various sources and radiometers used not only in the calibration of EOS and other Mission to Planet Earth (MTPE) instruments but also those used in field programs must be evaluated. The NIST/EOS transfer radiometers and other NIST/EOS radiometric equipment, e.g., sources, will be used to assess the accuracy of the radiometric calibration of the field equipment, and place all instruments in the intercomparison on a common scale so that performance issues can be addressed independent of radiometric calibration. It will then be possible to ascertain if instruments of different design, manufacture, and calibration method give the same result under similar measurement conditions. As appropriate, workshop and training activities will be included in the intercomparisons. The entire effort will be organized along the classic wavelength disciplines of visible/near infrared, shortwave infrared, thermal infrared, and microwave. The workshop activities will include presentations on instrument calibration and characterization, demonstrations of good radiometric/calibration technique, comparisons with actual field radiometers, and reviews of the results of the EOS Calibration/Validation efforts.

[†] Spectralon is a registered trademark of Labsphere, Inc., North Sutton, New Hampshire. Identification of commercial equipment to adequately specify the experimental problem does not imply recommendation or endorsement by the National Institute of Standards and Technology or the National Aeronautics and Space Administration, nor does it imply that the equipment identified is necessarily the best available for the purpose.

USGS/NAU Lunar Photometry

At the USGS and at NAU, both in Flagstaff, Arizona, long-term radiance measurements of the moon are being made in support of the on-orbit calibration, cross-calibration, and characterization of EOS visible and shortwave infrared EOS instruments (Kieffer and Wildey 1996). The moon is the only object accessible to all terrestrial orbiting spacecraft that is within the dynamic range of most imaging instruments and is stable enough to provide a calibration target. In Flagstaff, the USGS and NAU have constructed a dedicated observatory housing a visible/near infrared imaging telescope/camera system. Later this year, a shortwave infrared imaging system will be added to the observatory, extending the spectral radiometric measurement capability to 2.5 μm. These systems will make observations of the moon and sets of standard stars every photometric night over the bright half of the month over at least a 4.5-year continuous interval. USGS and NAU will use these data to construct a lunar radiometric model that will generate accurate exoatmospheric radiance data corresponding to EOS spacecraft instrument observations. The EOS/NIST and University of Arizona radiometers described earlier in this article will be used to verify the spectral radiance scale of the lunar radiance measurement calibration equipment.

Validation Field Programs

When the field-based and space-based measurements in the Level 1B data validation program are spatially and temporally simultaneous and the sensors are similar, the field measurements can be used to validate or verify the radiometric calibration coefficients of the space-based sensor. The EOS Calibration and Validation Scientists recognize the importance of promoting well-organized Level 1B data validation field programs in support of the EOS mission. In an effort to promote and foster these programs, the EOS Calibration and Validation Scientists and the EOS Deputy Senior Project Scientist are continuing the effort started by the Committee on Earth Observation Satellites Working Group on Calibration and Validation (CEOS/WGCV) (CEOS Pilot Cal/Val Dossier 1993). The goal of this effort is to produce a reasonably detailed international database of calibration facilities, test sites, and field instruments. This information will ultimately be used to identify participants for EOS calibration programs and common field test sites.

In order to improve the overall quality of the EOS instrument Level 1B data, validation field programs will begin in advance of spacecraft launch and will ultimately produce from each participant a representative, long-time series data set. In advance of the field programs, participants will: (1) clearly establish measurement, data analysis, and data reporting protocols, (2) fully characterize their instruments, and (3) calibrate their instruments using methods and artifacts traceable to a national standards laboratory.

In order to maximize the benefit to the EOS instruments, the calibration of Level 1B data validation instruments should take place before and after the field programs. In the case of radiometers, these pre- and post-calibrations should involve the near-simultaneous viewing of well-characterized radiance sources in a controlled laboratory environment.

Summary

The implementation of calibration and cross-calibration in the EOS Project includes a number of measurement programs. The NIST-supported MAPs in pre-flight and on-orbit calibration and cross-calibration are a key component of calibration in EOS. The MAPs currently include radiometric measurement programs, artifact round robins, measurement comparisons, workshops, and training. A measurement program in support of the on-orbit calibration and cross-calibration of EOS/MTPE and international sensors is the lunar radiometric characterization being performed by USGS and NAU in Flagstaff, Arizona. The Level 1B data validation programs are a third measurement activity which will verify the on-board calibration systems of orbiting EOS instruments.

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Summary Report of the EOS Test Sites Meeting — March 18-19, 1996

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INTRODUCTION

The EOS Test Sites Meeting was held on March 18-19, 1996 at NASA Goddard Space Flight Center under the sponsorship of the EOS Project Science Office Validation Program. The meeting focused on land-based test sites involving measurements for land, atmosphere, and vicarious calibration studies and was co-chaired by Diane Wickland, NASA Headquarters, and Chris Justice, University of Maryland/NASA Goddard. Attendees included 57 participants from government and university research organizations and from private industry.

The meeting was motivated by several long-term test site activities underway within the instrument and interdisciplinary science (IDS) teams as part of preparations for EOS AM-1 algorithm development and data product validation. It was deemed appropriate to convene a meeting to allow communication of existing activities between the teams, to communicate other EOS and non-EOS activities to the teams, and to identify areas for coordination, potential collaboration, and cost sharing. Specific objectives of the meeting were to summarize in an informal report the requirements, plans, and timelines for test site development in the early EOS AM-1 time-frame and to build the foundations for coordinated inter-instrument and instrument-IDS test site activities. These foundations were to be built upon in subsequent validation planning including the EOS Science Data Validation Workshop in May 1996.

The meeting was conducted in a workshop format. Summary reviews of pre-meeting materials provided by various EOS teams, and brief status reports on ongoing community activities were presented and provided a basis for subsequent breakout group sessions. The first round of breakout sessions included discipline groups for Vegetation and Land Cover; Radiation; Aerosols, Chemistry and Meteorology; and Vicarious Calibration. These groups were charged with developing the basis for a test-site measurement implementation plan, including specification of required measurement packages and potential measurement synergy from their discipline viewpoints. A second round of breakout group sessions was designed to develop synergies between the EOS measurement suites identified in the previous breakout group sessions and further develop a strawman implementation plan. For this second round of sessions, six groups were established including: Measurement Package Synergies, Scoping a Test Sites Initiative, Validation and Data Assimilation Activities, Data Management and Standards, Calibration Sites, and Organizing a Test Sites Initiative. Each of these breakout groups reported results of its deliberations in plenary sessions.

This article presents a summary of the meeting in the form of short reports from the four discipline breakout groups followed by the findings of the meeting which incorporate the discipline and synergy group findings. A detailed report of the meeting is available as a Validation Document from the EOS Project Science Office homepage on the World Wide Web (http://spso.gsfc.nasa.gov/validation/valpage.html).

RATIONALE FOR EOS TEST SITES PROGRAM

From the beginning of the EOS program, it has been recognized that use of satellite, aircraft, and surface-based observations is essential to achieving the principal scientific objective of increased understanding of the Earth as an integrated system. The global nature of Earth system processes dictates a sampling strategy that includes coverage of all important climatological zones of the globe including pristine regions as well as areas impacted by human activities such as biomass burning and industrial production. With satellites, global coverage is relatively straightforward; however, sufficient global sampling with aircraft and surface-based observations presents a major strain on both financial and human resources. In addition to their important role in scientific studies, aircraft and surface-based observations are required to provide correlative measurements and validation for the global satellite observations. Validation of the satellite observations is extremely important since global measurements of high accuracy spanning the full dynamic range of phenomena are required to achieve the program goals.

Aircraft and surface-based observations using both *in situ* and remote sensing techniques play a key role for scientific studies and for satellite data validation. Thus, the EOS Instrument Science Teams (ISTs) and Interdisciplinary Science (IDS) Teams have included such observations as elements of their investigations. Individually, the teams can accomplish limited objectives for their investigations, but the synergies of a coordinated, EOS-wide approach can produce much greater scientific payoff for the program. This is especially true for land-based test sites, since economies of scale and improved coordination with the many existing non-EOS land-based test site programs can be realized. Significant benefits can be realized in the EOS program by coordinating and integrating these activities to establish an EOS-wide, Land Test Sites Program.

CHARGE TO THE BREAKOUT GROUPS

Chris Justice gave the charge to the meeting participants. He began with a proposed definition of EOS Test Sites: EOS Test Sites are *Community* sites or locations where *multiple* surface and/or atmosphere measurements are taken for use in calibrating sensors or validating *multiple* EOS sensor data products and models. When the individual sites are combined as a network of sites, they provide an important step toward *global* representation.

The specific charge was:

1) Articulate the rationale for an EOS Test Site activity as part of the EOS Validation Program.

2) Design and scope the required/desired EOS Test Site activity to meet EOS investigator data needs, where possible building on on-going and planned activities.

3) Determine appropriate measurement packages suited to multiple products and instruments, including types, number, distribution, and frequency of measurements.

4) Examine synergy between land and atmosphere measurements.

5) Lay out a process for establishing the measurement protocols, the data system needs, and the interface to EOSDIS.

6) Identify the appropriate approaches and mechanisms for linking the EOS test site activity to: a) the broader U.S. Global Change Research community, and b) international measurement programs.

DISCIPLINE BREAKOUT GROUP REPORT SUMMARIES

Summary Report of the Vegetation and Land Cover Group - Warren Cohen, Chair and Stephen Prince, Rapporteur

For EOS, validation is needed for several vegetation and land cover parameters, including land cover type, land cover change, leaf area index (LAI), fraction of incident photosynthetically active radiation absorbed (FPAR), net primary productivity (NPP), and albedo and directional reflectance. Validation of these parameters may require measurements of additional parameters such as canopy and surface optical properties, digital elevation model (DEM) data, site biogeochemistry, biomass, percent vegetation cover, meteorology, CO_2 fluxes, and emissivity.

The group discussed in detail requirements and potential approaches for validating land cover and cover change and NPP. Also, requirements were discussed for the suite of variables including LAI, FPAR, reflectance, and albedo. Results from these discussions and those of the other groups have been incorporated into the section on findings of the meeting given later in this article. Details of the group discussions are given in the complete report, which will be made available on the Validation segment of the EOS Project Science Office homepage.

The discussion of measurement strategies considered requirements for Intensive Validation sites and Extensive Validation sites.

The Intensive Validation network is aimed at accuracy and multi-temporal measurements. As such, this network need not be globally representative, rather existing facilities such as the remaining sites from the Boreal Ecosystem-Atmosphere Study (BOREAS), the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) tower sampling sites, Long-Term Ecological Research (LTER) sites, agricultural experiment stations, and established physical environment monitoring facilities should be utilized and augmented. Large and uniform areas are essential; sites larger than a contiguous block of 3 x 3 fields of view of the sensors are needed to ensure correspondence of satellite sensor observations and field measurements.

The Extensive Validation network should aim to represent the ranges of the globally occurring values of the EOS parameters. The need for cross-calibration of measurement instruments and methods is paramount. Many of the sites will need to be outside the USA, and existing networks such as the IGBP Global Change and Terrestrial Ecosystem (GCTE) transects should be used where possible.

Summary Report of the Radiation Group — Alan Strahler, Chair and Thomas Charlock, Rapporteur

This group considered validation of fluxes at the surface and within the atmosphere, including radiative fluxes, sensible and latent heat fluxes, and chemical fluxes and validation of surface characterization, including land type, spectral BRDF, and description of vegetation canopy. Representatives from MODIS, MISR, CERES, ASTER and the Data Assimilation Office attended this group. Radiative fluxes and surface characterization were represented; however, microwave interests, the ocean, and moist processes were not represented thoroughly.

The Radiation Group recommended several classes of continuous surface validation sites:

Comprehensive Surface Tower sites to be constructed by EOS including a full complement of *in situ* observations for remote sensing validation. Six types of surfaces should be covered: barren, grassland, brush, broadleaf crop, deciduous forest, and needle leaf forest. There should be a comprehensive suite of surface instruments and periodic aircraft measurements at these sites.

Remote Sensing Physics sites at which measurements of atmosphere variables would be made to test remote sensing physics. These sites should have extensive suites of instruments and periodic aircraft campaigns should be conducted at these locations. Examples of such sites are the three DOE-Atmospheric Radiation Measurement (ARM) sites : Southern Great Plains (SGP) in the U.S., now operating; Tropical Western Pacific (TWP), planned; and North Slope of Alaska (NSA), planned. DOE supports extensive instrumentation at these sites, and periodic aircraft campaigns are also planned, some of which will require EOS support.

Regional Climate Trend sites to validate EOS "atmospheric subtraction" methods and to differentiate trends in surface, aerosol, and cloud properties. Taking advantage of existing and planned national and international networks, approximately 5 sites currently exist, and 40+ are planned through collaboration with the NOAA Surface Radiation Budget (SURFRAD) and GEWEX Baseline Surface Radiation Network (BSRN) projects. The objective is to have co-located radiometers and aerosol sunphotometers at these sites. EOS support will be needed to augment some sites and to allow aircraft campaigns at selected sites.

Discrete Validation sites that have a limited scope of measurements, but can be used to validate individual (discrete) EOS products. Existing and planned national and international networks provide targets of opportunity. Examples include: BSRN, ISIS (Integrated Surface Irradiance Study at NOAA), and GEBA (Global Energy Balance Archive in Zurich, Switzerland) type surface radiometer sites, and laser beam ceilometers at airports for cloud base height.

Summary Report of the Aerosol, Chemistry & Meteorology Group — Jinxue Wang, Chair and Eric Vermote, Rapporteur

Members of the MISR, MODIS, MOPITT, and SAGE III teams were represented in the Aerosol, Chemistry & Meteorology group. Requirements for sites, instruments, and measurements for the validation of data processing algorithms and geophysical data products of each instrument were presented and discussed. Examples of how EOS could build on existing monitoring systems are listed here:

DOE/ARM sites (SGP, NSA, and TWP) include aerosol measurements using lidars and sunphotometers and can be enhanced for measurement of CO, CH_4, and O_3 by using automated flask samplers and surface trace gas samplers. These enhancements would provide comprehensive sites for algorithm and geophysical data products validation. Aircraft overflights over the ARM sites are very important, and EOS AM-1 coordinated aircraft campaigns should be planned.

NOAA/CMDL Cooperative Flask Sampling Network (~ 60 sites worldwide) with profiling capability at most, if not all sites, are identified as potential long-term, trace gas sampling sites for geophysical products validation and correlative measurements. Profiling capability can be achieved by using the automated flask sampling system and small airplanes. The group strongly encourages the early implementation of the trace gas measurement program with automated flasks and small airplanes proposed by the Carbon Cycle Group of the NOAA/CMDL.

AERONET (Aerosol Sunphotometer Network) & **AEROCE** (Atmosphere/Ocean Chemistry Experiment), with enhanced measurement capability gained by including instruments to measure the downward and upward angular radiance distribution at the surface, are identified as long-term sites for geophysical products validation and correlative measurements.

NDSC (Network for Detection of Stratospheric Change) sites with IR Fourier transform interferometry, microwave radiometers, laser heterodyne spectrometers, UV/visible spectrometers, and lidars are identified as long-term sites for geophysical products validation and correlative measurements.

Summary Report of the Vicarious Calibration Group - Phil Slater, Chair and Jim Butler, Rapporteur

The Calibration Breakout Group met on Monday, March 18, and on Tuesday, March 19. The March 18 meeting addressed the following charges: 1) design and scope the required/desired EOS Test Site activity to meet EOS investigator data needs; and 2) determine appropriate measurement packages suited to multiple products and instruments.

The discussion of the first charge began with a clear statement of the goal of vicarious calibration at calibration test sites, namely to predict top-of-the-atmosphere (TOA) radiances in the spectral bands of sensors and to validate the geometric registration of sensor radiometric scenes. A list of some candidate calibration test sites for predicting TOA radiances was presented by Phil Slater. Each test site was examined with respect to its use by EOS instruments and its calibration benefits and liabilities. Tables were developed to summarize the test sites and their characteristics and to outline the required measurements and instruments.

The second meeting of the Calibration Breakout Group was held in the morning of March 19. The charge to the group was delivered by Chris Justice and included examining geometric calibration test sites, coordinating international participation in vicarious calibration, and examining test sites for thermal infrared calibration. Because of time limitations this last topic was not discussed.

Geometric test sites were discussed with regard to the calibration of EOS AM-1 instrument footprints. In the case of the ASTER instrument, candidate sites include Iowa road/field patterns and linear features such as bridges. For the MODIS instrument, possible use of the edges of playas and lakes was postulated, and for the ETM+ instrument, Jim Storey presented a summary of Landsat geometrical test sites.

The final topic addressed by the Calibration Breakout Group was the coordination of international groups interested in the vicarious calibration of satellite sensors. It was generally agreed by the group that the Committee on Earth Observations Satellites (CEOS) and its working groups and subgroups in calibration and validation offer a vehicle to promote coordinated international comparison campaigns.

FINDINGS OF THE MEETING

The findings of the meeting incorporate results of both the discipline and the synergy breakout groups in terms of consensus on test site characteristics, measurement groups, test site classifications, measurement suites, and data management and standards.

Consensus on Test Sites Characteristics

The meeting revealed considerable overlap between the needs and approaches identified by different disciplines for test site characteristics.

Homogeneity: Measurements are needed from sites that are homogeneous over areas larger than the footprints of instruments to be validated; 4-9 km^2 appears minimal.

Diversity: Measurement streams should be acquired from a diversity of land surface cover types, paying special attention to vegetation structure; 6-10 basic surface types (biomes).

Synergy: Data acquisition will be most effective with respect to both cost and scientific value if data are acquired in synergy with other measurements and measurement programs.

Ramp-up Strategy: Instrument costs are substantial and there needs to be a balance struck between the amount and cost of instrumentation and the number of sites. A balanced suite should prevail. The most costly (but most valuable) sites need to be expanded in number on a regular annual basis, adding a new increment each year.

Locations: Some possible existing and planned locations for instrumentation have already been identified at this meeting, including BOREAS, ARM sites, Brazil, etc. Existing networks, such as AERONET, AEROCE, BSRN, and LTER, should be utilized by adding value wherever appropriate to provide new data streams with proper characteristics. Other well instrumented long-term monitoring sites that are well distributed in the primary climatic zones within the U.S. are the U.S. Department of Agriculture-Agricultural Research Service experimental watersheds and the U.S. Geological Survey - WEBB (Water Energy and Biogeochemical Balance) sites.

Measurement Groups

The principal measurement groups are: Atmospheric Optical Measurements, BRDF Radiometry, Chemistry, Vegetation Structure, and Hydrology. Very little discussion was devoted to hydrology and existing watershed monitoring systems at this meeting. It was generally agreed that, in the future, additional emphasis will be needed to clarify the *in situ* data requirements for the hydrological aspects of the EOS platforms and program.

EOS Integrated Test Site Classifications

The requirements for EOS test site measurements can be met through an implementation plan consisting of different types of test site instrumentation. Discussion of classes of test sites developed from existing concepts formulated by the Global Terrestrial Observing System (GTOS) and the MODIS and CERES Instrument Teams. The concept of a hierarchical system (in terms of tiers) was developed for EOS Test Sites based on the required functionality, distribution, and level of instrumentation. It was recognized that individual measurement programs will continue and will be of use to the EOS community. Emphasis here was given to integration of land and atmosphere measurements for EOS Validation with an emphasis on EOS products.

Tier 1 — Intensive Field Campaign Sites. These sites are developed as part of the International Intensive Field Campaign Program supported in part by NASA such as the International Satellite Land-Surface Climatology Project (ISLSCP) - First ISLSCP Field Experiment (FIFE), the Boreal Ecosystem-Atmosphere Study (BOREAS), the Global Tropospheric Experiment (GTE) - Transport and Chemistry near the Equator in the Atlantic (TRACE-A) experiment, the International Satellite Cloud Climatology Project (ISCCP) - First ISCCP Regional Experiment (FIRE), and the planned Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). The sites have comprehensive multi-disciplinary ground-based instrumentation and repeated aircraft and satellite coverage. The field campaigns are intensive, lasting a month to a season and sometimes spanning successive years. The campaigns have an experimental focus and there is a large cost to supporting the field activities. They have been located in major biomes or climate regions. The multidisciplinary nature of the research is usually stressed. Such campaigns will be very useful for EOS Validation. In the context of long-term measurements and time series analysis, it may be desirable to maintain one or two of the test sites (as Tier 3 sites) beyond the duration of the intensive field campaigns, taking advantage of the capital investment in the site infrastructure and providing the possibility of long-term monitoring. There will probably be around ten of these international campaigns during the entire life of the EOS program.

Tier 2 — ***Super Sites.*** These sites are designed for long-term monitoring with a central focus on establishing a full suite of radiation and flux measurements, including broadband and spectral radiation fluxes, continuous carbon dioxide, temperature and moisture sounding, aerosol optical thickness and absorbing properties measurements, meteorological data, and surface characteristics data. Tall tower measurements are desired at these sites. The collocation of ground-based radar and cloud lidar measurements is highly desirable. Aircraft data will also need to be acquired at these sites. An example of this type of site is the DOE ARM SGP site. Given the full suite of measurements, it is unlikely that there will be more than 5 of these fully instrumented sites globally during the EOS timeframe. Currently, two additional sites are planned as part of this DOE ARM network (NSA and TWP). Interagency collaboration will be necessary to provide the full suite of instruments. International participation may provide the means to increase the number of such sites.

Tier 3 — ***Biome Tower Sites.*** These sites will provide long-term monitoring using instrumented towers at locations representing major biomes. These sites will be less well instrumented than the Tier 2 Sites, but will be at a larger number of locations. The sites could include eddy-correlation tower measurements of carbon dioxide and water vapor fluxes, selected radiation measurements, aerosol optical thickness, vegetation structure and phenology, land cover and land use characterization, soil fluxes, and physics and meteorology. Flask sampling of stable carbon isotopes will be a useful synergistic addition to these measurements. Site locations will represent major ecosystems and climatic regions. Emphasis will be given to process studies at these sites. An example is the Harvard Forest - Temperate Deciduous Forest Site. The BOREAS Thompson Site may also be continued to provide a long-term monitoring site in this category. The planned LBA Tower sites might also fall within this category. At present these sites have a strong bias towards the land community needs. The EOS Validation Program would benefit from the synergism resulting from collecting radiation and atmospheric data at these sites. Interagency coordination will be needed to increase the distribution of such sites. Internationally there are already strong indications that a global network could be established, for example, through IGBP coordination. The EUROFLUX network is an important step in this direction. With international participation there could be as many as 20-30 of these long-term sites in the EOS time frame.

Tier 4* — *Globally Distributed Test Sites. These sites provide an extensive site network aimed at a broader and more global representation of surface land cover, radiation, and atmospheric conditions. The sites will be permanent, for example the LTER network, the NOAA CMDL Flask Network, the BSRN, and the SURFRAD network. These different networks are each currently focusing on specific measurement sets and communities. *Emphasis for EOS Validation will be to strengthen such networks by building multi-measurement components and to broaden the global extent of the sites.* Emphasis at these sites will be on surface and atmosphere characterization for a limited number of variables, such as LAI, canopy optics, vegetation structure, land cover fraction, soil characteristics, land cover, surface radiation, and aerosol optical thickness. The primary purpose of these test sites within EOS will be global data product validation, e.g., land aerosols, atmospheric correction, land cover, LAI, and surface radiation data products. Of particular importance will be sites that can be used to address a broad range of parameters. Measurements may be continuous or may be taken at various intervals during the year and extend over a number of years. The sites will be used to capture seasonal and interannual variability and develop climatologies for the location. The instrumentation complement is likely to be less than at the Tier 2 and 3 sites, however, this will likely allow a greater number and much wider distribution of the sites. Occasional portable flux tower measurements may be possible. The minimal instrumentation needed for these sites means that there can be a greater number and wider distribution than for the sites in the previous categories. It may be that regional teams can be developed to provide consistent measurement and monitoring between these sites, which may, for example, fall along the IGBP Transects addressing ecology, hydrology, and atmospheric chemistry. Interagency and international cooperation will be needed to secure the network. However, interaction will be primarily between PIs. It is envisioned that there may be as many as 60 of these sites globally.

Tier 5 — ***Instrument Calibration Sites.*** A separate category of test sites is needed by EOS for instrument calibration. These sites will require unique properties of reflectance and emittance, with an emphasis on uniformity, typically non-vegetated. Examples of this category in the U.S. are the White Sands and Railroad Playa sites. There will be few test sites in this category (less than 5), and these sites will be well instrumented for vicarious calibration. It is recommended that international coordination between the various space agencies provide a network of these sites for use by multiple space-based platforms and instruments. Characterization of the atmosphere as well as the surface is critical. Aircraft overflights will be needed in association with the vicarious calibration campaigns. Geometric calibration sites were not discussed in any detail at this meeting, although it was recognized that an additional type of site may be needed for vicarious geometric calibration.

The role of EOS in the above activities will be to develop a network of sites to focus the EOS validation activities. *Emphasis will be given to augmenting existing networks with measurements needed to validate EOS data products rather than developing new networks.* Interagency and international coordination will be essential to develop the necessary global representation. The large number of *in situ* data collection programs currently in place and the apparent overlap with EOS objectives makes coordination a high priority. The spatial scale of the satellite data will place stringent needs for spatial sampling at the sites, and considerable emphasis will be needed in developing the appropriate methodologies. Coordination of aircraft overflights at the sites is needed.

Measurement Suites

Individual measurements identified for different instruments and disciplines were grouped into the following example of measurement suites which indicate synergy between measurements.

"A" Measurements: High priority, long term:
  Aerosol characteristics — Sunphotometers (e.g., the French CIMEL+ instrument) or Multi-Filter Rotating Shadowband Radiometer (MFRSR)
  Broadband radiant fluxes, up and down, short- and longwave
  Spectral radiant fluxes, up and down, short- and longwave (Cost-limited)
  Tropospheric CO profile
  O_3, CO, and CH_4 in column
  Simple meteorological data
  Uncalibrated TV cameras looking up and down to show site and sky conditions.
  Basic site characteristics (DEM, etc.)

"B" Measurements: In-depth, specific focus, rotating from site to site, and acquiring data for 3-6 month periods at a site:
  Temperature sounder
  Water sounder
  Directional radiance/reflectance measurements in SW and LW bands (Cost-limited)
  Tropospheric CO, CH_4, O_3 profile
  O_3, CO, and CH_4 column
  Aerosol size distribution
  Cloud lidar
  Cloud radar

"C" Measurements: Field measurements needed to support radiometry:
  Vegetation Index, LAI, FPAR, cover fractions, canopy structure, phenology, etc.

"D" Measurements: Aircraft measurements:
  Directional reflectance — e.g., ASAS (Advanced Solid-State Array Spectrometer), MISR airborne simulator, and TIMS (Thermal Imaging Multispectral Scanner) for boundary conditions
  CO, CH_4, CO_2, O_3, etc., profiles from aircraft
  Aerosols, fluxes, etc., from aircraft
  Tropospheric CO profile

"E" Measurements: Add-ons for IDS products:
  Sensible and latent heat fluxes
  Gas fluxes

Data Management and Standards

EOS test site data will need careful management to ensure open and timely availability, ease of accessibility, and archiving. Within the EOS Data and Information System (EOSDIS) DAAC system, the Oak Ridge DAAC is currently responsible for field data and, for example, the DOE funded ARM Data Archive is located at Oak Ridge. Test site data are also well suited to Principal Investigator (PI)-generated data systems using internet or CD-ROM distribution. The federated system currently being developed for EOSDIS might be well suited to validation data management and distribution. As part of the EOS Validation program, PIs will be responsible for managing their data effectively and in keeping with EOS data policy.

It will be important to ensure that measurements at different sites are made following set standards and guidelines. Specific findings and recommendations are:

Standards
- ◊ intermediate standards traceable to NIST (National Institute of Standards and Technology)
- ◊ baseline instrument calibration twice per year
- ◊ intercalibrate every 6 months (at a few sites)
- ◊ calibration teams using same sampling methods and processing techniques
- ◊ standards for geolocation data

Data Formats
- ◊ guidelines needed for data formats and metadata for ingest into EOSDIS
- ◊ the data systems must accept multiple data types (spatial, point, tabular)
- ◊ need to clarify the support that EOSDIS can provide and the role of DAACs

Quality Assurance/Quality Control
- ◊ done by test site scientist prior to submission to the data system
- ◊ DAAC does general checks for consistency and completeness
- ◊ PIs will need to adhere to documentation guidelines

Data Integration and Packaging
- ◊ need to develop integrated EOS satellite, aircraft, and *in situ* validation data sets
- ◊ integrate different data types into readily usable datasets for the scientists
- ◊ integrate data from different sites and link to relevant data from non-EOS sites
- ◊ clarify integration and packaging responsibilities including the role of the DAACs
- ◊ need georeferencing
- ◊ need processing history

User Feedback
- ◊ test site coordinating group needed for contact point, evaluation, coordination, etc.

RECOMMENDATIONS

Recommendations from the Meeting are:

1. The group recommended that there should be an EOS Test Sites Program:
   - ◊ There is a strong scientific rationale.
   - ◊ There is a strong desire to develop the integrated test site approach, including the EOS and broader scientific communities.

2. An EOS Test Sites Program should be developed to embrace four communities:
   - ◊ EOS Instrument and IDS Teams,
   - ◊ the larger USGCRP science community,
   - ◊ interagency test site network partners, and
   - ◊ international test site partners.

3. A small EOS Test Sites Steering Group should be established to develop and guide the integrated EOS Test Sites Program, with representatives from:
   - ◊ Instrument Teams,
   - ◊ IDS Teams,
   - ◊ EOSDIS,
   - ◊ U.S. agency partners, and
   - ◊ international partners.

4. EOS scientists will certainly participate in the Tier 1 campaigns, and the EOS Validation Program may wish to enhance the Tier 2 monitoring sites. However, it is recommended that the emphasis for the EOS Test Sites Program should be to build the capacity for Tier 3 and 4 activities. The development of multi-instrument, multi-product, and multi-discipline test site validation will be an essential component of the EOS program.

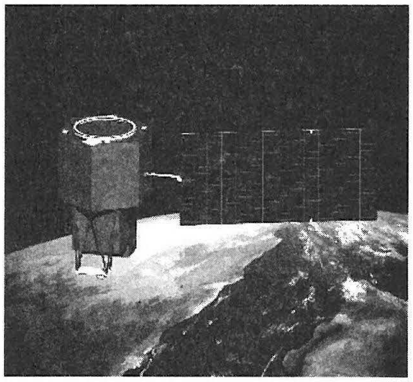
5. The EOS Validation and Calibration Programs should support a small number of vicarious calibration sites and work through CEOS to establish international cooperation for selecting, instrumenting, and supporting these sites for the benefit of EOS and its international partners.

6. EOSDIS (EOSDIS Core System or Federated System) should ensure the sound management, archiving, and distribution of EOS test site data to the EOS science community.
7. An EOS Pathfinder data activity should be undertaken to prototype the management and integration of test site data and satellite data in support of the EOS Validation Program.

CLOSING REMARKS

The co-chairs of the meeting, Diane Wickland and Chris Justice, thanked the participants for their diligence, enthusiasm, and excellent contributions, and stated that the accomplishments surpassed their expectations. ■

Advanced Land Imager Picked for First New Millennium Earth Science Flight



— **Douglas Isbell** (disbell@hq.nasa.gov), NASA Headquarters
— **Ernie Shannon** (ernest.j.shannon.1@gsfc.nasa.gov), NASA Goddard Space Flight Ctr.
— **Diane Ainsworth** (diane.e.ainsworth@jpl.nasa.gov), Jet Propulsion Laboratory

RELEASE: 96-67

An advanced, lightweight scientific instrument designed to produce visible and shortwave infrared images of Earth's land surfaces has been selected as the focus of the first NASA New Millennium program mission dedicated to the agency's Mission to Planet Earth enterprise.

The capabilities of the Advanced Land Imager instrument to be demonstrated on the flight will serve multiple purposes, according to Dr. Charles Kennel, NASA Associate Administrator for Mission to Planet Earth.

The new instrument will demonstrate remote-sensing measurements of the Earth consistent with data collected since 1972 through the Landsat series of satellites, which is used by farmers, foresters, geologists, economists, city planners and others for resource monitoring and assessment. In addition, it will acquire data with finer spectral resolution, a capability long sought by many elements of the Earth observation data user community, and it will lay the technological groundwork for future land imaging instruments to be more compact and less costly.

"We looked at nearly a dozen different mission concepts in some detail, and a land surface imaging mission clearly was at the top of this year's priority list," Kennel said. "It will ultimately enable first-class science, by validating breakthrough technology with clear potential capabilities, both commercially and to the future of NASA's Earth Observing System."

As designed, the Advanced Land Imager represents an approximate sevenfold decrease in mass and electrical power usage demands compared to the current Landsat-5 multispectral instrument. In addition, it extends the existing measurement capabilities through the incorporation of an advanced high resolution hyperspectral imaging "spectrometer-on-a-chip." This novel, wide-field observing system requires no scan mirror. It is built around a lightweight integrated silicon carbide structure and optical system, with an innovative in-flight calibration system.

Under project management by the Goddard Space Flight Center, Greenbelt, MD, the Advanced Land Imager will be developed from instrument technologies proposed by members of the existing New Millennium Integrated Product Development Teams.

For this mission, the team of industry partners will be led by the Massachusetts Institute of Technology's Lincoln Laboratory, Lexington, MA, a federally funded research and development center. Lincoln Lab and its partners will provide open access to U. S. industry regarding the design and performance of the Advanced Land Imager, with the explicit purpose of expediting the transfer of this technology into the commercial sector.

The instrument will feature ten-meter ground resolution in the panchromatic (black-and-white) band and 30-meter ground resolution in its other spectral bands, using a four- chip multispectral focal plane array that covers seven of the eight bands of the ETM+ to be launched on Landsat-7. Hyperspectral capabilities, which further split these bands into highly differentiated images, will be tested to show that they can be combined into traditional Landsat-equivalent data sets.

"The combination of multispectral and hyperspectral capabilities in a future operational system would preserve and continue the invaluable Landsat-based record of global land cover change, while opening up new windows on the Earth in areas like precision vegetation studies and more accurate mineral identification," Kennel said.

The spacecraft support structure, including advanced electrical power and data-handling subsystems, will be provided by Swales & Associates, Inc., Beltsville, MD, and Litton Industries, College Park, MD. The effort also will incorporate advanced spacecraft technologies made available through the New Millennium Integrated Product Development Teams.

The power and data subsystems will be provided through a Space Act cost-sharing agreement that calls for Litton to develop the hardware and integrate it into the New Millennium spacecraft, while providing the company with a two-year license to commercialize the technology. "This innovative arrangement, which includes a major commitment from Litton to integrate and deliver the hardware, represents an exciting new way of doing business for Goddard," said Center Director Joseph Rothenberg.

Further potential industry partnerships in the mission beyond those already identified will be solicited in a workshop to be held during upcoming advanced definition studies.

The total NASA cost of the first New Millennium Earth science mission, including its Small Expendable Launch Vehicle, has been capped at $90 million. Launch is planned for late 1998.

The current mission operations concept for the New Millennium flight has the spacecraft flying autonomously several minutes ahead of the ground track flown by the planned Landsat 7 satellite, to provide accurate paired-scene comparisons between the new and the traditional observing technologies. Evolutionary versions of the Advanced Land Imager would be candidates for flight on future generations of NASA Earth Observing System missions, beginning with the AM-2 spacecraft.

Formally started in NASA's FY 1996 budget, the goal of the New Millennium program is to identify, develop, and flight-validate key instrument and spacecraft technologies that can enable new or more cost-effective approaches to conducting science missions in the 21st Century. The overall program is managed by the Jet Propulsion Laboratory, Pasadena, CA, for NASA's Office of Space Science, Office of Space Access and Technology, and Office of Mission to Planet Earth, Washington, DC.

An artist's rendering of the spacecraft, in GIF and JPEG formats, may be accessed through the Internet. Via the World Wide Web, use the URLs:

http://www.hq.nasa.gov/office/pao/images/ali.gif
http://www.hq.nasa.gov/office/pao/images/ali.jpg

Via FTP, log on to ftp.hq.nasa.gov as anonymous and go to the directory /pub/pao/images. ■

Tantalizing Discoveries Mark Fast-Track Lightning Detector's First Year of Operation

— **Douglas Isbell** (disbell@hq.nasa.gov), NASA Headquarters
— **Steve Roy** (steve.roy@msfc.nasa.gov), NASA Marshall Space Flight Center

During its first year in orbit, a NASA lightning monitoring instrument called the Optical Transient Detector (OTD) has uncovered tantalizing links between space-based lightning measurements and the intensity of severe storms.

Launched into Earth orbit on April 3, 1995, by an Orbital Sciences Corp. Pegasus rocket, the orbiting detector has produced the first high-quality images of lightning on a global scale, according to principal investigator Hugh Christian of the Global Hydrology and Climate Center, Huntsville, AL. "In some cases, the images show up to 20 times more lightning flashes within clouds than are observed by the ground-based network," Christian said. "This is significant because lightning flash rates offer the intriguing possibility of assisting predictions of tornado formation."

Data from the instrument show that severe thunderstorms tend to produce lightning within clouds while the storms are building, and then more of a mixture of cloud and ground lightning as the storms dissipate. The quantity of cloud-to-ground lightning strikes, which can be detected by the present ground-based network, increases only after the storm has matured. "This case study indicates that space-based observations may provide a more advanced warning of severe weather," said Christian.

The instrument also has observed that more lightning is produced during the Northern Hemisphere summer than during the Southern Hemisphere summer.

The experiment was made possible by a streamlined design and development approach for a new technology system.

"This highly compact lightning detector represents a sophisticated new research tool in space," said project manager Roger Chassay of the Science and Applications Projects Office at the Marshall Space Flight Center, Huntsville, AL . "The Marshall team placed the lightning detector development on a fast track when given the opportunity to fly the instrument on the Orbital Sciences Corp. satellite, Microlab-1."

The detector was built, tested, and delivered in less than a year. "Our experience clearly shows that, for payloads involving small-to-medium size and complexity, we can definitely streamline the development process and provide flight hardware of high quality that produces valuable new science."

The Optical Transient Detector is a highly compact combination of optical and electronic elements. The optics and the electronics are a little bigger than a two-pound coffee can and a typewriter, respectively. In spite of its small size, the detector represents a major advance over previous technology, given its ability to detect lightning under bright, daytime conditions as well as at night.

The Optical Transient Detector is a pathfinder for a follow-on lightning detector called the Lightning Imaging Sensor (LIS), scheduled for launch in 1997 by a Japanese rocket on the Tropical Rainfall Measuring Mission (TRMM) spacecraft.

"Looking to the future, this instrument is showing us that lightning observations from geostationary orbit could be very valuable for severe weather prediction and warnings," said Christian.

Data from the lightning detector are analyzed by scientists at the Global Hydrology and Climate Center. The Center is operated under cooperative agreement between NASA, the University of Alabama in Huntsville, and the Universities Space Research Association.

Images and motion sequences of Optical Transient Detector cloud and lightning observations are available via the World Wide Web at the following URL: http://wwwghcc.msfc.nasa. gov:5678/otd.html. ■

AIRS and Outreach: Bringing Weather Down to Earth

— **Marguerite Syvertson** (mlss@scn1.jpl.nasa.gov), AIRS Outreach Coordinator, Jet Propulsion Laboratory

The goals of the AIRS Outreach Program are to educate and inspire teachers, students, and the public about the Earth, its climate, and remote sensing technology, and to familiarize them with the NASA programs that study our home planet. We plan to use a variety of venues to communicate with and involve our target audiences: the Internet and World Wide Web, teacher training, curriculum enhancements, weather stations, posters, displays, and partners such as universities, industry, and other governmental organizations.

Public Outreach

Homepage

The AIRS Homepage (http://www-airs.jpl.nasa.gov/) provides a wealth of information on AIRS and its role in global climate studies as well as links to several other NASA and climate programs. Overviews of the energy and water cycles, explanations of El Niño, and a clickable instrument with detailed descriptions are available. Recent scientific developments, articles, and papers have also been put on-line by the project. We have linked our homepage to those of team members (University of Wisconsin, University of California-Santa Barbara, and Goddard Space Flight Center), with other Mission to Planet Earth and EOS homepages, and with available up-to-the-minute weather sites such as WeatherWorld at University of Illinois and the Purdue Weather Processor. A search engine (Alta Vista) is also available from the homepage.

Events

AIRS has participated in a variety of public events at JPL and in the Los Angeles area. In 1995, JPL held an Earth Day festival in which we demonstrated our homepage and briefed the public on topical areas of interest such as El Niño, global warming, and atmospheric circulation. At the 1995 JPL Open House, the AIRS Outreach program pioneered the development and coordination of the Earth Walk, bringing together the various Mission to Planet Earth (MTPE) projects at JPL in a co-located area and partnering with the Multi-Angle Imaging Spectro-Radiometer (MISR) project on a Weather and Climate booth. This partnering concept is expanding at the 1996 JPL Open House June 8 and 9, with the creation of three thematic booths (Air, Land, and Ocean). We will be combining forces with the Microwave Limb Sounder (MLS), the Tropospheric Emission Spectrometer (TES), and MISR to cover the atmosphere from the ground up.

AIRS, in conjunction with the other JPL EOS projects, additionally has taken and plans to continue to take its display to local education and public fairs, conferences, and other events.

Education Outreach

The AIRS Outreach Program has benefited from its participation in the strategic planning process of the MTPE Education Office. Our programs and products have been developed and aligned under a subset of the implementation approaches identified by NASA Headquarters Education (Code FE): teacher preparation and enhancement, curriculum support, student support, and educational technology. Public Outreach covers those areas not included in formal education.

Teacher Preparation and Enhancement

Teachers are the key to integrating MTPE curricula into the classroom. Teachers use materials with which they are comfortable. By ensuring that teachers are competent and comfortable with the subject matter and materials that we provide, we have a higher likelihood of their use. Educating teachers about our Earth, climate, the AIRS instrument, and MTPE creates a multiplier effect — teachers will then share this knowledge with other teachers in their districts and with their students. The AIRS Project, in conjunction with MTPE, will also provide relevant materials to teacher training programs (universities) for use in their training curriculum. These new teachers can then use these materials and knowledge in their future classrooms.

California State University

JPL is developing a partnership with the California State University system (CSU) to increase scientific literacy and awareness of its non-science and education students and teachers around the state. The CSU system is the largest university system in the world with over 340,000 students; nearly 70% of the licensed teachers in California are CSU graduates. The agreement includes communicating the latest discoveries and technology to students, teachers, and the public via workshops and electronic media; providing user-friendly access to Earth and space science data; creating Earth and space science curricula for use in universities and K-12 classrooms; developing *in situ* experiments for use by students; and building working partnerships between faculty at both CSU and JPL.

AIRS plans to provide relevant data sets and assist with the coordination of access to other Earth science data for use in education and public workshops, data repositories, and curriculum development. We also plan to provide support to CSU in their development of Earth science curricula and measurement systems for use by CSU students and classrooms. Additionally, the experience of our staff as participants, lecturers, and coordinators in the Summer School for Earth Sciences and the Global Change Workshop for Teachers, hosted by JPL and the California Space Institute, will be useful in developing workshops for pre-service teachers and the public.

Teacher Interns

AIRS is investigating the value of teacher interns as a way of reaching out to our community. School districts benefit from the experience and leadership that can be brought back to their community — JPL and AIRS benefit from having experienced classroom teachers assist in the development of education materials and programs. AIRS hopes to invite a teacher to spend one to two years on this project and other projects within EOS and MTPE. This teacher will assist in developing curriculum enhancements and activities, websites, and other materials. In turn, the teacher will have the opportunity to learn about the MTPE program and how NASA is studying the Earth.

Curriculum Support

As guidelines for our educational products, AIRS is using national and state science frameworks such as the NRC's National Science Education Standards and the Science Framework for California Public Schools. The California State Science Framework is organized along six major science themes:

1. Energy
2. Evolution
3. Patterns of Change
4. Scale and Structure
5. Stability
6. Systems and Interactions

These themes link ideas across different scientific disciplines and are not used as subject material themselves. They integrate concepts and facts from the many science disciplines, provide a context for teaching these disciplines, and encourage better science writing in curriculum materials.

Our goals for curriculum enhancement development are to provide useful, relevant, and up-to-date information electronically for students, teachers, and the public. We have identified five science subject areas that relate to AIRS for our focus: clouds, El Niño, weather/climate, global warming, and carbon dioxide. For each of these subjects, we have created questions that address the various science themes above, as well as human interactions. These questions, by subject area, follow:

Clouds

◊ What are clouds? How are they classified? What are they made of?
◊ How do clouds form? How do they transport energy?
◊ How do clouds affect the radiation balance?
◊ What is the water cycle?
◊ How do clouds change?

◊ How do clouds indicate the stability of the atmosphere?
◊ How do clouds affect humans?

El Niño
◊ What is El Niño?
◊ What causes El Niño?
◊ How does El Niño affect weather around the world?
◊ How do ocean and weather patterns vary in an El Niño?
◊ What is the historical record of El Niños?
◊ How long does an El Niño last?
◊ How does El Niño affect human activity?

Weather and Climate
◊ What is weather and climate?
◊ What drives Earth's weather and climate?
◊ What is the energy cycle? How is energy transported by weather?
◊ What causes storms? How does weather change?
◊ How has weather changed over time (hurricanes, etc.)?
◊ What are the typical weather and climate patterns?
◊ How do humans affect weather and climate?

Global Warming
◊ What is the current distribution of temperatures?
◊ How does global warming occur?
◊ What are the effects of global warming on weather?
◊ How will global warming affect different parts of the world?
◊ How have global temperature and climate varied over time?
◊ What are the feedback mechanisms to keep Earth's temperature at equilibrium?
◊ How will humans affect global warming, and how does global warming affect humans?

Carbon Dioxide
◊ What is the carbon cycle?
◊ What causes carbon dioxide in the atmosphere, and how does it circulate?
◊ How does carbon dioxide affect climate?
◊ How does carbon dioxide get into the atmosphere?
◊ How has the amount of carbon dioxide varied over time?
◊ What is the composition of Earth's atmosphere?
◊ What role do humans play in the carbon cycle?

Each question has been assigned to a member of the science team; the resulting answers and information will be refined and enhanced by the outreach coordinator, who will also ensure that the answers are targeted at the high school/middle school level as defined by the California State Science Framework. The TIP teacher will also participate in the translation of the information into curricula once he or she is on the project.

This information, and related activities/experiments, will eventually be published on the AIRS homepage. An initial draft of the Cloud page is nearly completed and will be on-line shortly.

Student Support and Educational Technology

One of our most ambitious goals is to allow students to participate in their own "Mission to Planet Earth." We are investigating the use of student weather stations and weather data downlink (or Internet-link) sites so that students may take measurements of variables at their locations and compare them to measurements at other locations and to satellite data. We look to partner with and augment existing efforts such as the Global Learning and Observations to Benefit the Environment (GLOBE) project to leverage our efforts and reach the largest audience possible. We also plan to develop technology demonstrations, such as infrared measurement systems, that will allow students to understand how AIRS works.

Summary

The goals for our outreach program are to excite and educate students, teachers, and the public about Earth's weather and climate, and simultaneously increase their knowledge of science, technology, and the world around them. We look forward to working with other EOS and MTPE projects to bring outreach "down to Earth." ■

Interaction of Smoke, Clouds, and Radiation over Brazil (SCAR-B)

— **David Herring** (herring@ltpmail.gsfc.nasa.gov), Science Systems and Applications, Inc.

Introduction and Background

In collaboration with researchers from other U.S. and Brazilian agencies and academic institutions, NASA GSFC scientists recently completed the third in a series of campaigns to study the properties of aerosols and the effects of biomass burning on regional and global climate. Completed in September 1995, this latest campaign was focused on the properties and interaction of smoke, clouds, and radiation over Brazil; hence the name SCAR-B. (See the July/August 1993 issue of *The Earth Observer* for details on the first SCAR campaign.)

Trace gases—such as CO_2 and CH_4—contribute to the Earth's greenhouse effect by trapping and containing heat from geothermal and incoming solar radiation. Theoretically, increasing the concentration of these trace gases in the atmosphere will proportionally amplify the greenhouse effect, thereby raising the average global temperature. Scientists estimate that deforestation and corresponding biomass burning are responsible for a significant percentage of the increase in atmospheric CO_2 concentration since the beginning of the industrial revolution, around 1850.

Biomass burning releases particulates into the atmosphere that affect its chemistry and physics on local, regional, and global scales. For example, smoke particles can act as cloud condensation nuclei (CCN) interacting with clouds to create smaller, more-numerous cloud droplets, resulting in more dense clouds. Theoretically, increasing CCN should result in an increase in cloud albedo—unless it is compensated with black carbon absorption—having a net cooling effect on climate. However, satellite analysis shows a decrease in cloud albedo as a function of smoke concentration, so further studies are needed to better understand the physics involved.

Paradoxically, biomass burning affects atmospheric dynamics in ways that promote both global warming and regional cooling trends. Which trend will prove greater in the long run? According to SCAR-B Scientist Peter Hobbs, of the University of Washington, the warming trend will prove greater in the long run since the residence time of CO_2 in the atmosphere is much longer than that of particles.

Yet, scientists are only just beginning to understand the problem in ways that allow them to construct models of the interactions of smoke, from burning vegetation, with clouds and radiation. Goddard scientists hope to refine these models further so that they can monitor the effects of forest fires, using satellite sensors such as the Moderate-resolution Imaging Spectroradiometer (MODIS), over much greater temporal and spatial scales.

Why Brazil?

By far, most—about 80 percent—of the anthropogenic CO_2 released into the atmosphere comes from industrialized, northern hemisphere countries. Consequently, SCAR-A (for America) focused on characterizing the urban pollution released among highly populated regions in the eastern United States.

But what about the remaining pieces of the puzzle? Biomass burning accounts for about 23 percent of the CO_2 emissions worldwide today. According to Darold Ward, of the U.S. Forest Service, about 80 percent of the biomass burned annually is in tropical countries in Africa and South America. About 40 percent of the total burned comes from deforestation.

Brazil is a logical environment in which to extend the SCAR campaign. Its widespread slash- and burn-agricultural practices account for a significant portion of the tropical burning and deforestation taking place. It is therefore important to characterize the aerosols and trace gases being released into the atmosphere there; as well as to monitor how those emission products are transported to other parts of the world.

More significantly, an infrastructure already exists in Brazil to support a campaign as complex as SCAR. A Memorandum of Understanding was already in place between the U.S. Forest Service and IBAMA (the Brazilian equivalent) for sharing technology and knowledge on natural resource management. Specifically, the U.S. Forest Service has been involved in exchanging information with IBAMA on fire management, prescribed burning, control of fires, air quality considerations, and ways of minimizing adverse effects of smoke from fire management activities. Later, Tim Suttles, previously of NASA Headquarters, and Volker Kirchhoff, SCAR-B co-project scientist from INPE, were able to formulate another Memorandum of Understanding to cover the SCAR experiment.

In addition to the scientific equipment and expertise that Brazil has to offer, state-of-the-art computer networks and communications systems were already in place to facilitate rapid data transmissions and communicating of last-minute mission plans among geographically distributed researchers. During the previous two campaigns, SCAR scientists found that cellular phones were an effective, efficient medium for staying in touch—Brazil's cellular phone system worked nicely.

Flight operations planning requires access to the latest meteorological information, as well as intelligence reports on where the fires are burning. Good communications between scientists—sometimes located out in the field or even a continent away—and aircraft pilots is essential for optimizing flight paths, in response to constantly changing meteorological conditions, to meet the data collection objectives. To address this problem, Elaine Prins set up a World Wide Web server at the University of Wisconsin-Madison on which she continuously posted the latest meteorological data—from GOES —over the entire continent of South America. Several times per day SCAR participants at IBAMA accessed these data via the Internet and relayed them to flight mission planners.

Although SCAR-B data analysis will be ongoing for some time—and conclusive results will take years to pin down—there is one immediate payoff from the campaign. A close, ongoing working relationship between American and Brazilian scientists has been established. Collaboration between our two countries has proven to be successful and greatly beneficial, not only in terms of valuable data exchanged, but also in terms of scientific knowledge and expertise shared. Hobbs summed up his working relationship with the Brazilians in one word—"excellent".

Prior to SCAR-B, Brent Holben, of GSFC, installed a network of sunphotometers throughout Brazil to measure aerosol size distributions and concentrations, as well as their effects on solar radiation. This network permits continuous monitoring of aerosol optical thickness, sky radiance, and ground sampling of aerosols for at least the next several years. This long-term collaboration with Brazilian scientists will yield a spatially wide dataset on the emission of trace gases and particles from biomass burning in Amazonia and cerrado regions.

Goals of SCAR-B

Perhaps the foremost goal of the SCAR campaign in Brazil was to obtain measurements of the rates of emissions of trace gases and particulates from biomass burning, and to observe the influence of atmospheric processes on these emission products. During SCAR-C (in the northwestern United States), Paulo Artaxo, of the University of São Paulo, and Hobbs observed that forest fire smoke particle size varies quickly during the first few hours of its lifetime, growing very quickly. Then, after the first few hours, particle size remains fairly constant. Particle morphology is important to understand how the aerosols will behave chemically in clouds, as well as how they will affect incoming solar radiation. "We learned [during SCAR-C] that in a given fire there is high correlation between its infrared signal and the rate of emission of particulates and trace gases from it," adds GSFC's Yoram Kaufman, SCAR-B co-project scientist. "This is important for the MODIS fire algorithm because it shows that the algorithm will be more than just counting fires."

Understanding how emission products are transported by wind currents in South America is also key. "There are very nice results from trajectory analyses that clearly show strong transport of aerosols from biomass burning from Brazil into [the atmosphere over] the South Atlantic and entering into the global circulation," Artaxo states. "We also observed some emission products **being** transported from the Amazon Basin to the Pacific through the Andes Mountains."

Another goal during SCAR-B was to characterize the physical and radiative properties of smoke particles from biomass burning. Explains Lorraine Remer, of Science Systems and Applications, Inc., "We had an interesting picture emerge from the SCAR-A campaign of urban industrial aerosols. But we knew from Brent's [Holben] sun photometer data from earlier years that [our characterization of aerosols in America] wouldn't be applicable to Brazil because the aerosols are different there."

Indeed, there is even variation in Brazilian aerosols found over the cerrado, or dry savannah, region versus those found over the rainforest of Amazonia. "My interest was to obtain data to see how aerosols differed and varied regionally," Remer states. "I wanted to know if different types of smoke in Brazil could be modeled by one model, or would I need several?"

As mentioned previously, collecting data on the interaction of smoke particles with clouds was another important goal in SCAR-B. Interestingly, Kaufman and Robert Fraser (GSFC) noticed that smoke affects clouds over the northern rain forest regions of Brazil, but does not seem to affect the clouds over the cerrado. They don't yet fully understand why, but speculate that cloud drop radii in clouds over the cerrado region may already be too small to be significantly affected by smoke. In Africa, they note, the cerrado type of aerosols from biomass burning is more dominant, and this finding may be important to understanding their capability to affect clouds.

In addition to its impact on the atmosphere, biomass burning affects the health of surrounding vegetation and the ecosystem it supports. Using SCAR-B remote sensing data of different land surface covers in the presence and absence of smoke, Alfredo Huete (University of Arizona) and the MODIS Land Discipline Group hope to develop improved vegetation indices enabling them to monitor the conditions of tropical vegetation using MODIS data once that sensor is launched.

SCAR-B Instrumentation and Measurement Strategy

In addition to the ground sunphotometer network, aircraft and satellite platforms were employed to gather remote sensing data during SCAR-B. The NASA ER-2 flew 80 research flight hours carrying a payload consisting of the MODIS Airborne Simulator (MAS), the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), the Cloud Lidar System (CLS), a Spectral Electro-Optic Radiometer (SEOR), and solar and infrared flux radiometers. On average, the ER-2 was flown at an operating altitude of 20 km. Primarily through the efforts of Michael King, SCAR-B co-project mission scientist, the MAS data system was upgraded prior to the campaign from a 12-channel, 8-bit digitizer to a 50-channel, 12-bit digitizer.

Aircraft *in situ* measurements, as well as sampling of aerosol particulates and trace gases, were made by instruments aboard the University of Washington's C-131A and the Brazilian INPE Bandeirante aircraft, flying about 75 and 90 research hours, respectively. These aircraft were flown at multiple altitudes to help gather data on how smoke particles and trace gas properties evolve over time and as a function of height.
Satellite remote sensing data were obtained from the Geostationary Operational Environmental Satellite (GOES), Meteosat, Landsat Thematic Mapper (TM), and Advanced Very High Resolution Radiometer (AVHRR) to complement the aircraft and ground measurements.

Conclusions

According to Kaufman, the SCAR-B campaign was a great success and met the scientific expectations of the participating scientists. "It has produced a unique and unprecedentedly large database to study the effects of biomass burning on atmospheric processes and climate, and to prepare new techniques for remote sensing of these processes from space."

For example, as a result of the SCAR campaigns, Kaufman and a group of MODIS researchers developed a new method for remote sensing of aerosols over land. The method involves identifying dark pixels using the

2.1-µm channel and then predicting the reflectance in the blue and red channels using the measured reflectance at 2.1 µm. Kaufman states that this algorithm is now a major part of his present MODIS aerosol retrieval algorithm. Kaufman adds that the image data from MAS and AVIRIS, covering 2 million square kilometers, will give us detailed spectral information on thousands of fires and the related smoke emitted from them. These remote sensing data will be complemented with spectral data from Holben's sunphotometer network. Additionally, Hobbs will have detailed data on the chemistry and optical properties of emission products.

Kaufman expects the SCAR scientists to spend several years retrieving valuable science from the data set, so it will be a while before they are ready to draw substantive conclusions. Data from the campaign are currently being processed by the respective data collecting agencies. Eventually, these data will be stored at the NASA Langley Research Center Distributed Active Archive Center (DAAC) and made available to the science user community from there.

For more details on how to access SCAR-B data, contact Sue Sorlie, SCAR-B data manager, at sorlie@magician.larc.nasa.gov; or call her at (804) 864-8660.

Future Plans

The SCAR team plans to conduct at least one more campaign in northern California in September 1997 to revisit their investigation of smoke and fires from biomass burning in the Pacific Northwest. Prior to that, SCAR members plan to participate in the following campaigns:

- ◊ Subsonic Aircraft Contrail and Cloud Effects Special Study (SUCCESS) in April and May 1996, to determine the radiative properties of cirrus contrails and to contrast them with naturally occurring cirrus;
- ◊ Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX) in July 1996, to measure atmospheric aerosols emanating from industrial centers in North America transported over the Atlantic Ocean; and
- ◊ overflights of the Marine Optical Buoy (MOBY) in August 1997, to investigate MAS infrared-derived sea surface temperatures, visible/near-infrared water-leaving radiances, and radiometric calibration of the MAS measurements. ■

Left to right are Dave McDougal (NASA LaRC), Project Manager; Lorraine Remer (SSAI), Mission Scientist; Yoram Kaufman (NASA GSFC), Co-project Scientist; Luiz Gylvan Meira Filho (AEB), President of the Brazilian Space Agency; a Brazilian ambassador; and Volker Kirchhoff (INPE), Brazilian Project Scientist. ◁

photos by Dave Herring

The ER-2 flies at very high altitudes (up to 70,000 feet). Pilots must wear special suits to provide oxygen, as well as maintain a constant pressure and temperature. Pictured in the background is NASA ER-2 pilot Jan Nystrom standing next to the ER-2 cockpit. ▷

NSIDC DAAC User Working Group Meeting Report

— **Konrad Steffen** (koni@seaice.colorado.edu), Chair PoDAG, National Snow & Ice Data Center
— **Ron Weaver** (weaver@kryos.colorado.edu), DAAC Manager, National Snow & Ice Data Center

BACKGROUND

The Polar DAAC User Working Group (PoDAG) met April 1-2 at Goddard Space Flight Center. This was the tenth meeting of the User Working Group, and the second as the NSIDC DAAC-only user working group. (Previously PoDAG served as a joint advisory group to the Alaska SAR Facility and NSIDC DAACs.) We provide here a very brief description of materials presented and the action items arising from the PoDAG. Please contact Ron Weaver if you have any questions about material presented.

NSIDC DAAC Update

Roger Barry, NSIDC DAAC Scientist, provided an overview of activities during the past 12 months. Highlights of his presentation included the following:

- ◊ Total user requests filled by NSIDC during 1995 remained roughly the same as 1994. However, over 60% of the requests came from new users. SSM/I-derived products remain the largest portion of NSIDC data sets accessed.
- ◊ Several new products are nearing completion. These include a combined 1978-95 snow cover extent-sea ice extent product covering the Northern Hemisphere; updates to the Historical Arctic Rawindsonde Archive; a Greenland ERS-1 SAR mosaic on CD-ROM (in conjunction with GSFC scientists); and weekly snow cover extent, 1978-present, derived from passive microwave data.
- ◊ NSIDC is working with Mark Anderson, University of Nebraska, on the development of a sea ice melt onset product derived from passive microwave data.
- ◊ NSIDC DAAC will acquire SMMR and SSM/I historical orbital brightness temperature data for 1978-95 from the Marshall Space Flight Center DAAC, due to the closure of the MSFC DAAC. Several other data sets will be transferred to NSIDC, such as the SSM/I NESDIS sensor counts for F8, F10, F11, Fleet Numerical Meteorology and Oceanography Center (FNMOC) antenna temperatures, and the Wentz antenna temperatures for F8 and F10. Transition will occur during the remainder of 1996.
- ◊ The Data Center staff continues its collaborations with several IDS and instrument teams, including POLES and CRYSYS IDS groups, MODIS, ASTER, AMSR, AIRS, MISR, and GLAS Teams.
- ◊ Routine data set production continued for approved passive microwave and AVHRR products. The production staff transferred, processed, and archived over 10,000 polar AVHRR scenes. SSM/I gridded products (TBs, and Sea Ice Concentrations) have been produced through August 1995.
- ◊ NSIDC has completed a 16 bit version of the HDF conversion tool for SSM/I products. This tool is available on the FTP site (sidads). NSIDC will suspend production of new data sets in HDF until the tool's availability is adequate for the user community. NSIDC will launch a user survey to query the user community about the preferred data format (HDF vs. flat file structure).

Polar Pathfinder Interactions

Jennifer Francis reported on the Polar Pathfinder group (AVHRR, TOVS, Passive Microwave, Radar Altimeter, Radarsat) which met in Boulder (March '96), to determine standard formats (time, grid, filename, organization, variable names). They agreed to process first the Aug. '87-'93 time period, and then the pre '87 time period. Further, they agreed to merge all their geophysical products in a data cube (common low-resolution data set) with 100 km grid resolution on a daily basis (~500 Mb/year). TOVS data for April 87 - Nov. 88 are already archived at NSIDC (water vapor at 5 levels).

The group also has written an article (Roger Barry, *et al.*) that summarizes the Polar Pathfinder projects. It will be published shortly in *EOS, Transactions*, American Geophysical Union.

Glacier Mapping and Mass Balance Assessment

The Interdisciplinary Sciences Investigation on climate, erosion, and tectonics, led by Brian Isacks at Cornell University, has evolved to focus on mountain glaciers and the climate system. Mountain glaciers are sensitive indicators of climate change, and with new developments in satellite glaciology, multi-temporal high-resolution monitoring of certain glaciers could provide a valuable data set for climate system modeling. The theoretical, satellite-based, glacier/climate data assimilation machine was presented. This regional climate model would use passive microwave, visible, and radar satellite data as data inquest to derive mass and heat fluxes on the glacier surface. The selection of 23 present and planned glacier monitoring sites was presented.

MODIS Polar Products

At the November, 1995 MODIS Science Team meeting, NSIDC reported on two possible approaches for producing Level 3 global and polar grids for the MODIS snow and ice products. The preliminary work shows that errors are minimized when producing the Level 3 product directly from the Level 2 data, instead of regridding the Level 3 product. However, the proposed ISCCP-derived grid for MODIS Level 3 products may not be suitable for polar applications. Based on the concern raised by users, including the polar community, the Science Working Group for AM Platform (SWAMP) adopted a new policy which states: no single gridding scheme can be imposed on the EOS AM teams for Level 3 products — there is too much variation in the requirements of the group (e.g., polar products vs. cloud products).

AVHRR Survey of the Modeling Community

A small user survey of the modeling community was conducted by Greg Flato, AES-Canada, to determine the usefulness of the proposed AVHRR data set. Results suggest that a 5 km data set would be ideal for regional climate modeling (10 responses total). The GCM modeling community showed no interest in the 1 km AVHRR data set.

AVHRR 1 km Archive

Three years ago the AVHRR 1 km archive was begun at NSIDC. Since the inception, a total of 78 different users made data requests, and the data use has grown steadily. The cost to the DAAC of the archiving and distribution of the 1 km data set has been around $80 - 120 K/yr. Increased user numbers are anticipated with the availability of the navigation software on the network. The generation of polar-wide geophysical products is now funded by the NASA Pathfinder project. As currently planned, the AVHRR Pathfinder products will be produced at three scales: 25 km, 5 km, and 1.25 km. All products will be generated on grids identical to the Equal Area SSM/I Earth (EASE) polar grid.

NOAA Operational Sea Ice Products

Rob Grumbine of NOAA's NCEP reported that National Center for Environmental Prediction (NCEP) now produces an operational sea ice concentration product based on the SSM/I F-13 passive microwave data, using the NASA team algorithm with the W. Abdalati correction coefficients in polar stereographic projection on a 25 km grid. The updated product is available on the following FTP account : 140.90.192.85 in the subdirectory pub/ice.

SMMR Sea Ice Intercomparison

Comparison between Pathfinder and GSFC SMMR brightness temperatures showed differences of up to 5 K (18 GHz/H). Large differences in Tb were found resulting from bad scan lines in the Pathfinder data set. The ice concentrations along the marginal ice zone differ consistently, up to 20 %, for the two data sets. The GSFC data set was "hand cleaned," and it is suggested that the Pathfinder data set needs some additional data cleaning.

SSM/I Intercalibration

The SSM/I F8, F10, F11 (1988-1995) data have been cross-calibrated by Frank Wentz to an accuracy of 0.1 K. The regression coefficients to convert F10, F11, to F8 have been released. The cross-correlation was only done for orbits with a time difference of less than 30 min. A detailed report is available from Remote Sensing Systems, Technical Memo 010395.

AMSR Sea Ice Products

Konrad Steffen will chair a study committee to determine which of several sea ice concentration and extent algorithms will become the at-launch algorithm for the Advanced Microwave Scanning Radiometer (AMSR). The AMSR is proposed for flight on the PM-1 platform. This meeting will be held in July 1996.

Passive Microwave Ice Tracking

Barry Goodison (AES Canada) reported on the cross-correlation of ice features (image matching) to derive ice motion based on 85 GHz SSM/I passive microwave data. This work has been published by T. Agnew, AES/ Canada. Goodison went on to describe the CRYSYS IDS Team goals. The original focus of CRYSYS was on hydrology; this has shifted to the study of climate variability of cryospheric variables over a range of scales (regional to global). The research group concentrates on the development and validation of local, regional and global models of climate/cryospheric processes and dynamics, and on improving understanding of the role of the cryosphere in the climate system.

Don Cavalieri (GSFC) also reported on the recent progress in ice motion mapping using wavelet analysis (in space domain) to derive ice motion vectors from SSM/I passive microwave data. Comparison with buoy data showed good agreement for ice speed and ice direction in the Beaufort Sea.

Federation and Recompetition of DAACs

Dixon Butler (NASA HQ) briefed PoDAG on the current status of the federation of EOSDIS and recompetition of DAACs. The NASA study team, headed by Butler, is drafting a new scenario which embodies the concerns of the NRC Board on Sustainable Development.

PoDAG members raised several issues to be considered by the study team:

- ◊ What role does a user working group play in the new Federation?
- ◊ How does NASA maintain continuity and consistency in a long-term data time series (such as NSIDC's passive microwave sea ice concentration data set) in the recompetition scenarios?
- ◊ PoDAG members suggested that new federation members should provide expanded information services rather than replacing existing DAAC services.

John Dalton, the Deputy ESDIS Project Manager, also spoke with the PoDAG membership. Dalton relayed his current view of recompetition and federation. In general terms, he echoed Butler's comments of the previous day. PoDAG membership again raised the issue of data consistency and continuity in a recompetition environment.

RADARSAT

Robert Thomas (NASA HQ) informed attendees that there might be a charge of U.S. $600 per image for RADARSAT data outside the Alaska SAR Facility (ASF) station mask, including those scenes down-loaded from the tape recorder within the ASF mask. NASA is negotiating with the Canadian Space Agency to resolve this issue. ■

ECS Hosts First Meeting of Ad Hoc Working Group for Consumers

— **Lori J. Tyahla** (ltyahla@eos.hitc.com), Science Office, ECS Project, Landover, MD

The EOSDIS Core System (ECS) hosted the first meeting of the Ad Hoc Working Group for Consumers (AHWGC) on March 14, 1996 at the Landover, MD facility. The overall objective of this group is to collect further information about the EOSDIS user community to refine the ECS User Characterization Team's methods and results. The group was formed by the EOSDIS Data Panel and is co-chaired by Bill Emery (University of Colorado) and Dave Emmitt (University of Virginia). Members include representatives from IDS Teams, EOS Instrument Teams (ITs), and EOSDIS Distributed Active Archive Centers (DAACs). Representatives from the ECS Science Office and NASA/GSFC are also active in the group.

The initial efforts of the group have focused on collecting detailed information regarding the data needs of the NASA EOS-funded Interdisciplinary Science (IDS) Teams. This information is used by ECS developers in designing and sizing various components of the ECS, including data servers, distribution hardware, archive structure, and processing requirements. A packet of information was sent to each IDS Team with a request for each team to identify the data required by all of the team members in each of three time periods. The details of the methods and results can be found in *Input Data Requirements of EOS-Funded Interdisciplinary Science (IDS) Teams* (URL http://ecsinfo.hitc.com/sec1/ahwgc.html).

There were three main objectives of the March 14 meeting:

◊ review analysis of the "volume distributed will equal twice the volume produced" design assumption and provide recommendations;

◊ discuss methods for managing user loads on the system to maximize system performance and provide recommendations; and

◊ review the results of the analysis of the IDS Team data needs.

The outcome of the meeting was a list of assumptions, definitions, and recommendations regarding these issues. In addition, the group provided a list of topics that will need to be addressed at some future time by the ECS Project.

Guiding Principles

◊ Users/providers must sense fairness (non-discrimination), responsiveness, and stability.

Assumptions/Definitions

◊ Users/providers will behave differently tomorrow than they do today.
◊ Emphasis must be on having plans for adapting to the change.
◊ The system will saturate (when we include all potential users) with user requests/demands reducing performance, throughput and data delivery:

- saturation is likely a function of time of day
- subscriptions and media distribution impact saturation differently than does network access
- system is susceptible to saturation due to unreasonable network data requests

◊ X is the volume of data put into, i.e., "push," the archives per year.
◊ N is the ratio of pull/push.

- N refers only to data "pulled" by the following three groups of users: Instrument Teams for QA/QC, IDS Teams for all purposes, and data pulled by general users. Data Pull for product generation is accounted for separately and sufficient resources are available for this purpose.

- ◊ N, e.g., 2, is assumed to represent "pull" or data "out the door" without replication.
- ◊ N is also a system average but known to vary between data products.
- ◊ The ECS architecture is capable of handling 16X given sufficient hardware.
- ◊ DAACs are in the best position to choose the appropriate means of managing pull demand that approaches or exceeds their capacity.

Key Findings by the AHWGC

- ◊ Initial IDS plus Instrument Team QA/QC data pull should not exceed 1.5X and may be closer to 1X, given the history of pre-launch overestimating the volume of data needed by Quality Control.
- ◊ N = 2 is reasonable for initial design, i.e., 2X.
- ◊ Estimation of non-EOS research demand is bounded by:
  10 petabyte/year (33X) extreme
  2 petabyte/year (7X) reasonable
  0.5 petabyte/year (2X) probable
- ◊ 10% of data products account for 90% of pull.
- ◊ Currently, tape and CD ROM are the more frequently requested modes of data delivery — this is very likely to change as ftp capability becomes more common and network capacity is significantly increased.

Recommended User Load Management Options

Although current estimates of IDS and IT demands are within the ECS 2X resource limit, as the user demand (pull) approaches the operational capacity of ECS (initially 2X), the DAACs (or Earth System Information Partners [ESIPs]) will need to exercise some form(s) of system management that will avoid having the level of service to EOS investigations fall below some minimum level of performance (TBD).

The AHWGC has identified the following options for managing user demands that approach or exceed the existing ECS capacity. It is assumed that system managers will be monitoring push/pull in real time and will have adequate warning (on time scales of weeks) of impending saturation.

Short-Term Options (days to months):

- ◊ Load leveling to minimum acceptable performance (in terms of turnaround time) multiple copy options:
  - mastering CDs
  - ftp staging
  - WWW sites
  - PIF (Potential Impact Filter) — user services interception of requests for services with significant impact on a system's marginal performance

Long-Term Options (months to years):

- ◊ Temporal charging — "sooner costs more"
  - vouchers for core users
  - bidding between DAACs for new data sets/services
  - Cooperative Agreement Notices (CANs) to lever age private sector participation in meeting user demands increase N (up to 16X) by purchasing more hardware

Last-Resort Options (more long term than short term):

- ◊ Prioritization of requests based upon a to-be-developed NASA policy
- ◊ Pricing designed to limit demand
- ◊ User authorization resulting in discrimination

There were also many questions raised at the meeting including:

- ◊ Who will manage system access/performance?
- ◊ Who (how) will policy be set for these management practices?
- ◊ How will this policy/practice be reviewed and communicated to the science user community?
- ◊ How do we collect input on these issues from the science user communities?
- ◊ Can we have a federation ESIP manage this aspect much as a network arbiter enforces the network Acceptable User Practices (AUP) and resolves conflicts?
- ◊ Will value-added providers be treated differently from other external users? What happens if the value-added provider trades in timeliness and the system approaches saturation?

Overall, the meeting was very successful with the group reaching consensus on several issues. These recommendations were formally documented by the co-chairs of the group and delivered to the ESDIS Project and NASA Headquarters. ■

Real Data: Understanding the Process of Data Production

— **Dawn Guilmet** (d.m.guilmet@larc.nasa.gov), NASA Langley Research Center
— **Bruce Barkstrom** (brb@ceres.larc.nasa.gov), NASA Langley Research Center
— **James F. Kibler** (j.f.kibler@larc.nasa.gov), NASA Langley Research Center

In 1995, Bruce Barkstrom wrote an article in *The Earth Observer* giving an introduction to modeling error detection and the quality of data production. He developed a methodology to predict when "good" (error free) data would start to be generated. He plotted logistics curves (the probability of good data being produced as a function of time) using values based on his involvement in the ERBE satellite project. The purpose of this paper is to compare the values he used with values determined by analyzing the records kept of the ERBE Data Management Meetings, giving the reader a synopsis of the data produced by this analysis.

In 1980, the ERBE Data Management Team started development of the ground processing system to produce science data products from ERBE scanner and non- scanner instruments on three satellites. The ERBE Data Management Team Meetings, also known as Wednesday Afternoon Prayer Meetings, occurred at scheduled intervals (the intervals varied over the years from every week to once a month); and 9 to 20 people (averaged 15 to 16 people) attended them. Jim Kibler maintained meeting records in an action item list which included their start date, contact person, review/ meeting dates and details, and end date. From these records, stored in binders over the last sixteen years, it is possible to extract useful information such as the length of action items, number of action items occurring per month, and the kind of items occurring. This information can then be computerized, manipulated, and compared to the cost model proposed by Barkstrom. As one could imagine, sixteen years produces a great number of action items (approximately six hundred), and computerizing this amount of data is a non-trivial activity. At the time of generation, the records were computerized; however, computer systems changed, became obsolete, and were lost—leaving only the printouts behind.

The key activities in the time between the start of meetings and launch in 1984 included coding, testing, and documenting software, designing and testing the instrument, and allocating responsibilities. Figure 1 shows the number of action items that were produced per month. The initial peak (point a) drops off corresponding to the completion of pre-launch tasks. After the launch in 1984, there was a period when data were coming in, but errors were not obvious. A build up of work crests in mid-1985 (point b) and falls off until the beginning of data archival in mid-1986 (point c). By the peak in 1985, the team had discovered most of the errors and were dealing with them. As data archival commenced, there was a sharp increase in action items tapering off until the fall of 1992 (point d). At this point, due to instrument malfunction, archival of another data product began.

In reference 1, Barkstrom made some guesses to plot a logistics curve governed by the following equation:

$$q(t) = \frac{1}{1 + p_0 T_r exp(-\frac{t}{\lambda})} \quad (1)$$

where $q(t)$ is the probability that good data are produced, p_0 is the rate of error discovery, T_r is the mean time to repair the errors, t is time, and λ is "error discovery lifetime." The following is a table that shows Barkstrom's guessed values and the values determined from the data:

Table 1. *Constants for Logistics Curve*

	Barkstrom's Values	Current Values
λ	0.3 years	0.45 years
T_r	0.5 years	0.14 years
p_0	24/year	30/year

The current values were based on the data from the period after launch (point c on Figure 1). We used this particular region of data because it followed an exponential, and the other regions of Figure 1 did not seem to follow one. Later in this paper the differences evidenced in the logistics curve by these discrepancies will be discussed. We found the error discovery lifetime for this ten-month interval by dividing the total number of items by ten. To find the mean repair time, we added the time it took to complete all of the items in the ten month period together and divided it by the total number of items. To find λ the following relationship was assumed:

$$< \lambda >_{model} = \frac{\int_0^T t \, exp(-\frac{t}{\lambda}) dt}{\int_0^T exp(-\frac{t}{\lambda}) dt} \qquad (2)$$

where T is the period, t is the time, λ is the error discovery lifetime, and $\langle\lambda\rangle$ is the mean weighted time. In this instance, the exponential acts like a weighting function. Now to find $\langle\lambda\rangle$, we use the experimental data and the discrete form of Eq. (2):

$$< \lambda >_{experiment} = \frac{\sum_{i=1}^{k} n_i t_i}{\sum_{i=1}^{k} n_i} \qquad (3)$$

where n_i is the experimental data (equivalent to the exponential weighting function), t_i is time, and the sum is over the number of months. The Δt that would appear in both of the sums can be neglected because in our case they are unitary and constant. After finding $<\lambda>$ from Eq. (3), we set it equal to the solved form of Eq. (2):

$$< \lambda >_{experiment} = \frac{\lambda - (\lambda + T) exp(-\frac{T}{\lambda})}{1 - exp(-\frac{T}{\lambda})} \qquad (4)$$

after the equations are in this form, we find λ by iterating (this method reproduced simulated data with acceptable accuracy). With values determined using this procedure, the Figures of $q(t)_{model}$ (the logistics curve presented in the reference) and $q(t)_{experiment}$ (the logistics curve found using the values determined in this paper) matched fairly well. $Q(t)_{experiment}$ started with a

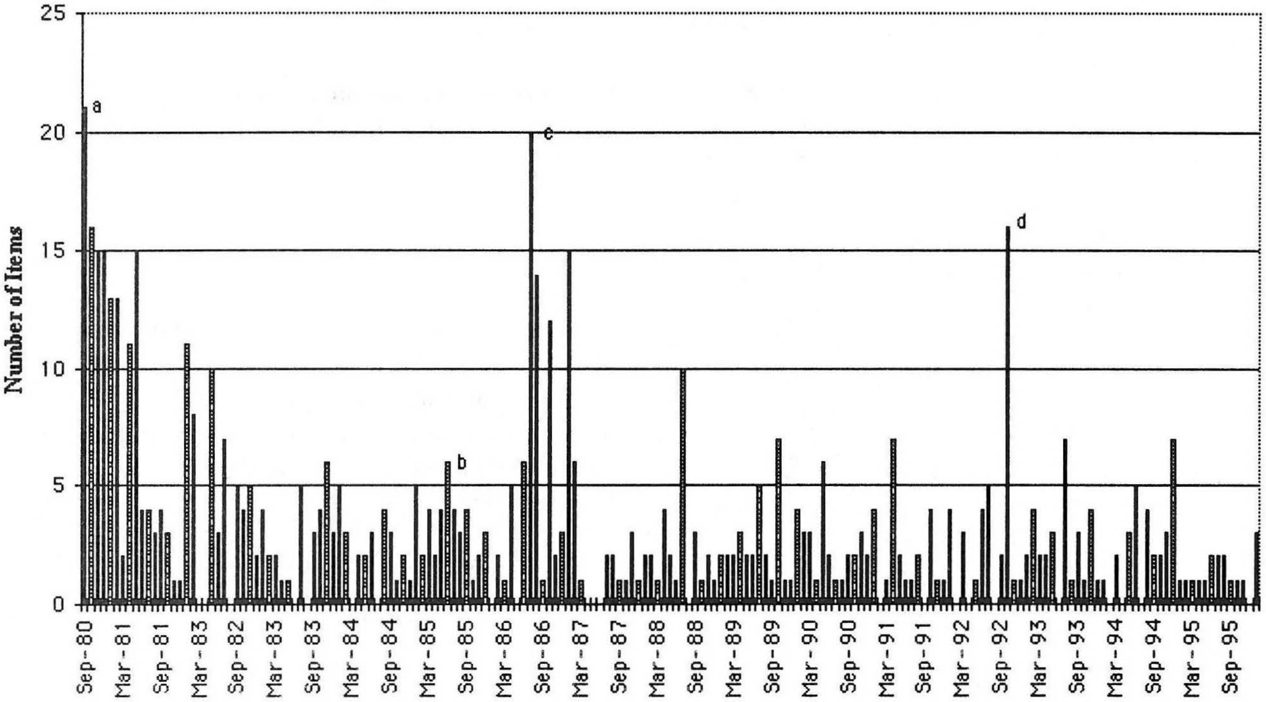


***Figure 1**. Number of New Items by Month*

13% higher probability of accurate data (around 23%) than $q(t)_{model}$, but took about three months longer than $q(t)_{model}$ to reach greater than 90% probability of accurate data.

Another way to think about these data is how long it took to complete the items. Figure 2 displays the number of days it took to complete each item in order of item occurrence. Now, if we were to determine how many items fell into certain time bins, a feeling for item completion time could be deduced (one could think of this as putting all of the items in Figure 2 in order, from item with the longest completion time to item with shortest completion time). We chose bins with a width of ten days producing Figure 3. Figure 3 shows the number of items versus the number of days to complete those items. Hence, there were 72 items that took one to ten days to complete. Looking at the figure we can see that most of the jobs took less than three months to complete, and more than half of those took less than a month. Pre- and post- launch items were also charted; however, there did not seem to be a significant difference between any of them. Using a similar method to that described above, we determined that the data in this Figure fit an exponential fairly well.

Some of the data looked at thus far seem to fit within the framework of Barkstrom's model. The following are areas where more work needs to be done, and any comments or insights are welcome:

1) The functions that describe archival and pre-flight data need to be determined.
2) It would also be valuable to compare conclusions from this data set with those from other data sets. We are looking into this; however, if anyone has access to or has done analysis on data sets like these, please let us know.

References:

Barkstrom, B., 1995: The good, the bad, and the useful: Do things ever go right? *The Earth Observer*, 7, 46-49. ■

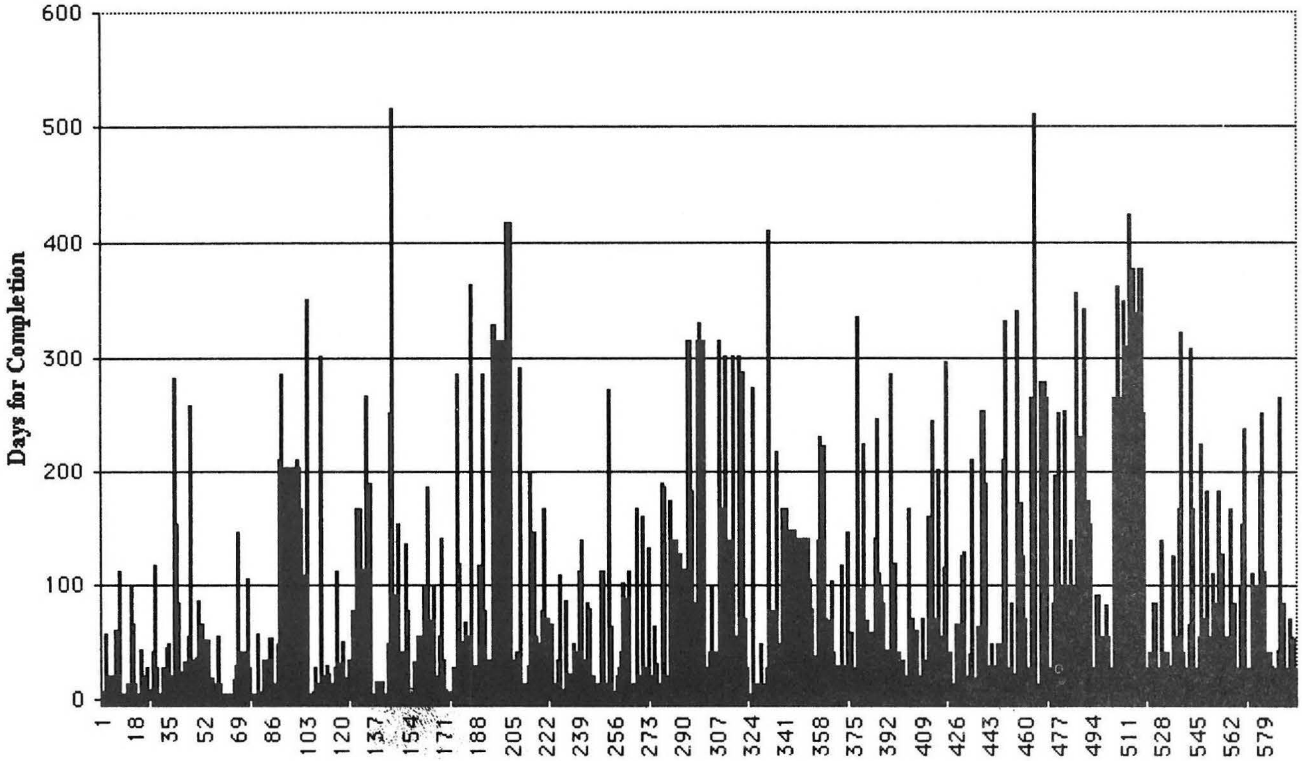


***Figure 2.** Time for Completion of Items*

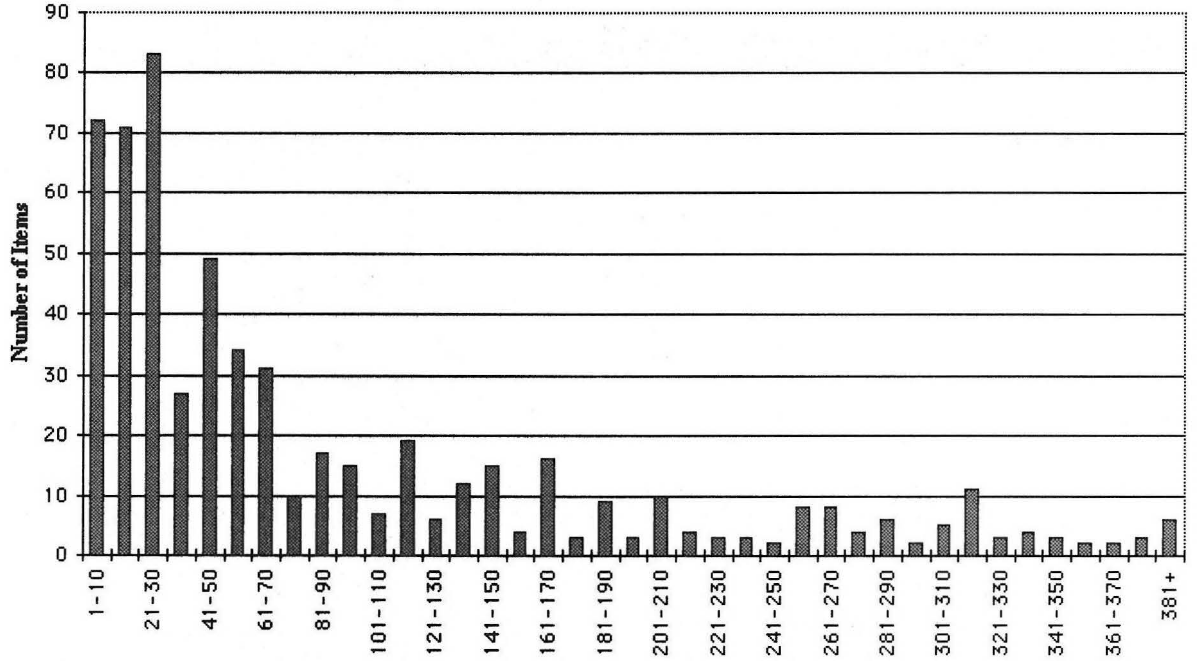


Figure 3. *Number of Items Vs. Completion Time (days) (Total)*

NASA Awards Pre-College Grants to Nine Universities

— **Sonja A. Maclin** (NASANews@luna.osf.hq.nasa.gov), NASA Headquarters

RELEASE: 96-97

NASA's Office of Equal Opportunity Programs announced the selection of nine minority universities to receive a three-year grant, Pre-college Awards for Excellence in Mathematics, Science, Engineering, and Technology (PACE/MSET), for educational outreach projects.

Each university will receive up to $100,000 per year for the three years of the grant, based on performance and availability of funds under the program.

The grants are intended to help students who have historically been underrepresented in college-preparatory mathematics and science classes gain the skills necessary to pursue science, engineering, and related fields in college.

The selected universities to receive grants are:

California State University, Los Angeles, CA
Elizabeth City State University, Elizabeth City, NC
Fayetteville State University, Fayetteville, NC
Hampton University, Hampton, VA
Lehman College, Bronx, NY
Northwest Indian College, Bellingham, WA
Pasadena City College, Pasadena, CA
Southwestern Indian Polytechnic, Albuquerque, NM
Saint Augustine's College, Raleigh, NC

The grant program targets institutions of higher education, especially Historically Black Colleges, and Universities, Hispanic Serving Institutions, Tribal Colleges and other minority universities whose student enrollment of underrepresented minorities exceeds 50 percent.

The PACE/MSET grant program is sponsored by the Office of Equal Opportunity Programs, Washington, DC.

Quality Assurance Methodology for EOS Products

— **Bob Lutz** (rlutz@ltpmail.gsfc.nasa.gov), Hughes STX Corp., ESDIS Science Office

Introduction

This article presents a strategy for Quality Assurance (QA) for the generation and archiving of EOS products. The process will require the participation of the Instrument Science Teams (ITs), the DAACs, the Interdisciplinary Science (IDS) investigators and representatives from the general science community. One of the goals and challenges of EOS will be to ensure that EOSDIS satisfies the QA science requirements of all these communities. The material is being presented here to expose the proposed QA methodology to as much of the EOS community as possible. Information is provided at the end of this article on how to become involved in the process.

Often, before the EOS/EOSDIS era, i.e., before 1990, detailed QA procedures had been incorporated into the processing algorithms *after* the launch of the satellite. This approach was sometimes *ad hoc* and incomplete, and the organization and content of the archived QA parameters were poor. Within EOS, forethought needs to be given regarding the real-time processing needs and the storage demands necessary for the inclusion of QA data into EOSDIS, due to budgetary constraints and capacity allocations. Furthermore, a definition of a QA procedure early in EOS, will maximize the potential for the long-term utilization of this type of data.

The general issue of QA of EOS products was initially raised at a Data Processing Focus Team (DPFT) meeting in April 1994. Scoping of the effort began within the EOSDIS Project Science Office (Steve Wharton) and has since transitioned to the ESDIS Science Office (H. K. Ramapriyan). Draft versions of QA Procedural Plans have been circulated among the ITs and DAACs, soliciting them for comments. The latest draft (June 1995) has been presented at several science team meetings and workshops. In addition, a QA Functional Components document has been prepared, to serve as a template for the anticipated IT-DAAC QA Plans.

Definition of Quality Assurance

The Panel on Data Quality (Mike Freilich, Chairperson) has proposed that quality control consists of three entities: calibration, quality assurance, and validation.

QA is defined as a process whose objective is to identify and flag data products, which obviously and significantly deviate from the expected accuracies for the particular product type. The QA process will be performed at the granule or smaller level, where a granule is defined as the smallest entity of a dataset for which inventory entries are maintained. We are recommending that the QA definition also include any quality control process that can be done before the product is released to the general science community.

The QA analysis of EOS products will consist of one or more of three possible functional components:

1) ***Product Generation Executive (PGE) QA Analysis*** Within this component, the data products are produced (presently at a DAAC) from science algorithms supplied by the instrument science teams. It is anticipated that numerous QA parameters (operational and product-related) will also be generated from these algorithms. As a part of this process, some of these generated QA parameters may be summarized and possibly subsetted. These QA parameters will then be sorted and subdivided amongst the product metadata, the data product, possible external QA products, and operational processing logs.

2) *DAAC QA Analysis (Optional)*
The role of the DAACs in the science QA process will be determined by the Instrument Science Teams. Some DAACs may perform extensive science QA as negotiated between them and their respective ITs, while others may see no science QA performed at all at their site. Possible DAAC QA functions may be the monitoring of operational QA parameters and summary QA statistics generated from the previously discussed PGE analysis. Visual examination of the data products or statistical analyses of the QA parameters may also be done within this component. It is anticipated that the results of these analyses and the specification of possible problems will be sent electronically to Science Computing Facility (SCF) personnel in the form of QA reports. The SCF scientists would then investigate the problem and evaluate the situation.

3) *SCF QA Analysis*
The instrument teams will be ultimately responsible for the science QA of their data products. A subset or the entire data product (and the related external QA products) may be examined by scientists at the SCF, visually or statistically. It is also possible that the SCF scientists may want some (or all) of the operational QA information and summary QA statistics. In addition the instrument teams may also be receiving QA reports from the DAAC(s) processing the data. As a result of the SCF QA analysis, it is possible (though not probable) that the SCF scientists will modify the data products. A more-likely scenario will see only an update of the metadata files within the product. The final step within this analysis will entail the instrument team recommending that : 1) the data should be archived and released to the general public; 2) the data should be put in temporary storage and that further investigation is warranted; or 3) the data are incorrect and reprocessing is necessary.

Metadata

Quality control information will be inserted into the core metadata at two levels: validation parameters will be contained at the collection level, e.g., a data set, many granules, and QA measures at the granule level. QA attributes within the core granule metadata include :

1) *QA Collection Stats*
A set of three general QA flags will be used to indicate the overall quality assurance level of the granule:
(a) Automatic Quality Flag — Flag set by the algorithm processing software within the PGE.
(b) Operational Quality Flag — Flag set by DAAC personnel (optional QA analysis).
(c) Science Quality Flag — Flag set by the SCF scientists.
A text comment field will be available to supplement the above flags.

2) *QA Stats*
Generic numerically-based flags will be associated with each granule. These flags include :
(a) QA Percent Missing Data,
(b) QA Percent Out of Bounds Data,
(c) QA Percent Interpolated Data

It should be noted that some of these flags may not be informative for all levels, e.g., all Level 3 data are interpolated data.

To indicate individual product QA information, specific QA measures will be established by the instrument teams. The set of QA attributes will be contained within the non-core metadata. It is strongly suggested, if possible, that a common approach be developed by the ITs for the inclusion of these non-core QA results into the metadata. This would provide users with a consistent format in their interpretation of project-wide QA. In addition, these product specific metadata parameters should be general and adaptive enough to accommodate a changing QA data stream over the life of the project.

Users of QA parameters

QA parameters may be used by several "types" of users:

1) ITs will use QA parameters for the monitoring of the "health" of their data products. It is possible that some of these data, based on decisions of the ITs, may only be "internal" and not archived at the DAAC, e.g., algorithm QA parameters.

2) ITs, whose products use other ITs' products as

inputs, may need supplemental QA information from the other ITs. Some of the desired incoming QA parameters may be of the "internal" nature, but caution and careful documentation must be used if non-archived QA information is utilized in any decisions.

3) The IDS teams and non-EOS funded researchers, may need extensive QA, e.g., individual data point QA Flags, in their generation of higher level EOS products.

4) The general science community may utilize QA statistics quite differently from the above groups, in that these parameters may be principally used to "screen" data for potential usefulness. It is quite possible that the metadata QA statistics may be the most important parameters for this community. This group may also provide recommendations (though not binding) pertaining to the characteristics of the non-core QA data, i.e., what resolution and which QA parameters from the PGE analysis should be ultimately archived.

Implementation

A proposed implementation scheme for the development of a comprehensive QA methodology is now presented for the ITs, the DAACs, the IDS teams, and the user community. The procedure is a two-step iterative process. During the first stage of the process, data are gathered independently from each group through solicitation of each group's QA procedures and needs. The collected data will be compiled and distributed to the various groups. A workshop will be convened where representatives from all groups will participate in the formulation of a project-wide QA approach. During the second stage each group may fine-tune its own individual plans to accommodate the needs of others.

Involvement of the ITs and the DAACs

As algorithms mature and lessons are learned from the implementation of earlier versions of the software, the QA methodology will evolve. We, therefore, recommend a sequence of the writing of QA Plans, coinciding with the anticipated greater needs of QA information for the IT software deliveries. The first part of this sequence would occur before the workshop. A suggested QA Plan has been formulated and circulated among the ITs. It solicits information pertaining to the general characteristics of the functional QA components, as well as a detailed description of the inputs and the outputs for each component. The proposed QA Plan also provides a section and an opportunity for the ITs to indicate QA statistics that they would desire from other ITs.

1) ***Draft QA Plan for Version 1***
Within this version of the QA Plan, the ITs may not be able to provide specific details of their QA products because of the immaturity of their algorithms. General QA elements are expected to be known though, and specification of this preliminary information will aid data-dependent ITs in the planning of their software. We recommend that Draft QA plans be generated by the ITs between their Beta and Version 1 releases (June 1996). This will allow sufficient time after the generation of such draft plans for an information exchange workshop (October 1996).

2) ***QA Plan for Version 2***
From information learned during the workshop, as well as lessons learned from the implementation of Version 1, final QA plans will be generated by the ITs. We recommend that the delivery of these plans (April 1997) should be several months before the implementation date of Version 2 software to provide ample time for data dependent ITs to understand and incorporate the incoming QA data products.

Involvement of the IDS Teams and the User Community

The IDS teams will be notified, through their panel chairpersons, that there is a need within the project for their input to QA Procedures within EOS. Inputs regarding their needs for QA information will be gathered through the Ad Hoc Working Group on Consumers (AHWGC).

A panel will be formed of researchers representative of the science user community. Members of the DAAC User Working Groups (UWGs) may compose some of the panel. Other interested members of the science community will be welcomed to be part of this group. We recommend that the AHWGC work with this group to formulate a method to solicit comments from the user community on the proposed content of the archived QA metadata. Within the workshop, representatives of the panel will be encouraged to comment on the proposed content of the sub-granule QA information as specified in the IT Draft QA Plans.

Summary

The successful completion of this activity will allow:

- an early clarification of the respective roles of the DAACs and the ITs with regard to QA. This will enable both entities to better plan their development and resource allocation;
- the ITs and the DAACs to modify their individual QA plans after surveying the plans of other ITs;
- data-dependent EOS ITs, i.e., ITs receiving EOS standard products from other ITs, to review how the received EOS-QA data could be used in their processing algorithms;
- the IDS teams to comment on the QA parameters that are intended to be generated by the ITs and the possibility that these comments could be incorporated by the ITs in final versions of their software;
- the ECS contractor to plan ahead in the design of the QA metadata within the HDF data structure; and
- the user community to comment on the content and organization of QA that may be generated for a product.

This article, the fourth draft of the QA Procedural Plan, and the QA Functional Components document are found at URL address http://eos.nasa.gov/esdis (ESDIS homepage). Please use the comment option found there or e-mail Bob Lutz (rlutz@ltpmail.gsfc.nasa.gov) to indicate an interest in the information exchange workshop planned for October 1996. ■

WHAT'S NEW? WHAT'S NEWS? WHAT'S NEW?

WHAT'S NEW?

The following URLs are the most recent additions to the EOS Project Science Office World Wide Web homepage at URL http://spso.gsfc.nasa.gov/spso_homepage.html. Additions will be provided in each issue. Send your most recent links to Winnie Humberson (winnie@ltpmail.gsfc.nasa.gov) to be included in this column.

NASA Ocean Primary Productivity Workshop
http://seaeagle.gsfc.nasa.gov/~http/PP_Wkshp_announc.html

Earth System Science Education Project
http://spso.gsfc.nasa.gov/eos_homepage/news/announce.html

Reshape Implementation Options Study
http://spso.gsfc.nasa.gov/eos_homepage/misc_html/intro_options.html

Calibration Web Page
http://spso.gsfc.nasa.gov/calibration/calpage.html

Validation Web Page
http://spso.gsfc.nasa.gov/validation/valpage.html

EOS Chemistry Study
http://spso.gsfc.nasa.gov/eos_homepage/misc_html/intro_chemstudy.html

Science Calendar

Week of June 10	ASTER Science Team Meeting, Pasadena, CA. Contact Anne Kahle (anne@aster.jpl.nasa.gov) at (818) 354-7265, or H. Tsu (tsu@ersdac.op.jp)
June 25-27	AIRS Science Team Meeting, Silver Spring, MD. Contact George Aumann (hha@airs1.jpl.nasa.gov) at (818) 354-6865.
June 26-27	SAGE II Science Team Meeting, NASA/LaRC. Contact Lelia Vann (l.b.vann@larc.nasa.gov) at (804) 864-9356.
July 9-11	EOS Calibration Panel Meeting, NASA/GSFC. Contact Jim Butler (butler@highwire.gsfc.nasa.gov) at (301)286-4606.
September 18-20	CERES Science Team Meeting, NASA/LaRC. Contact Theresa Hedgepeth (t.c.hedgepeth@larc.nasa.gov) at (804) 825-0001

Global Change Calendar

June 10-12	4th International Satellite Direct Broadcast Services Symposium for NOAA Polar-orbiting Operational Environmental Satellite (POES) Users, Annapolis, MD. For more information contact (301) 345-2000, ext. 135, e-mail: POESUSER@infrmtcs.com.
June 10-14	USRA/GSFC ESS Lecture Series, Global Change and the Americas, Goddard Space Flight Center. Contact Paula Webber; Tel. (301) 805-8396, e-mail: paula@gvsp.usra.edu.
June 16-20	American Society of Limnology and Oceanography Annual Meeting, University of Wisconsin at Milwaukee. Call for Papers. Contact Susan Weiler, Fax: (509) 527-5961, e-mail: weiler@whitman.edu.
June 17-21	Second International Scientific Conference on the Energy and Water Cycle, Washington, D.C. Contact International GEWEX Project Office at (202) 863-0012 (gewex@cais.com) or Judy Cole at Fax: (804) 865-8721 (cole@stcnet.com).
June 24-27	Second International Airborne Remote Sensing Conference and Exhibition: Technology, Measurements, and Analysis, San Francisco, CA. Contact Robert Rogers, ERIM Conferences, Box 134001, Ann Arbor, MI 48113-4001; Tel. (313) 994-1200, ext. 3234, Fax (313) 994-5123, e-mail: raeder@erim.org. Information available on WWW at http://www.erim.org/CONF/.
July 9-19	International Society for Photogrammetry and Remote Sensing (ISPRS), Vienna, Austria. Contact Lawrence Fritz, Tel. (301) 460-9046, Fax: (301) 460-0021.
Augut 4-9	SPIE Annual Meeting, Denver, CO. Contact Diane Robinson, Tel. (363) 676-3290 Ext. 357, e-mail: diane@spie.org.
August 20-22	William T. Pecora Memorial Remote Sensing Symposium, "Human Interaction with the Environment - Perspectives from Space," Sioux Falls, SD. Contact Gary Johnson (pecora13@edcserver1.cr.usgs.gov), Technical Program Chair.
September 14-18	National States Geographic Information Council, 6th Annual Meeting, Doubletree Hotel, Tucson, Arizona. Contact Ammie Collins, Tel. (603) 643-1600, Fax (603) 643-1444, e-mail: NSGIC@AOL.COM.
September 23-27	European Symposium on Satellite Remote Sensing III, Taormina, Italy and Conference on Sensors, Systems and Next Generation Satellites. Call for Papers. Contact Steve Neeck, Tel. (301) 286-3017, e-mail: Steve_Neeck@ccmail.gsfc.nasa.gov.
November 4-7	ECO-INFORMA '96 — Global Networks for Environmental Information: Bridging the Gap Between Knowledge and Application, Lake Buena Vista, FL. Contact Robert Rogers, Tel. (313) 994-1200, ext. 3234, Fax (313) 994-5123. In Europe, contact Otto Hutzinger, (+49) 921-552-245 or 155.

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