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## Editor's Corner

On March 18, Mr. William Townsend, acting Associate Administrator for the Office of Mission to Planet Earth, announced the selection of winning proposals for end-to-end science missions known as Earth System Science Pathfinders (ESSP). Under the terms of the competition, these ESSP proposals included not only instruments and data analysis, but also spacecraft, launch vehicle, and satellite command and control systems, and were cost capped at $60 M for the first mission and $90 M for the second mission. These principal investigator-led missions are to be developed from approval to launch in just 3 years (for the first mission) with little direct NASA oversight, and are expected to yield exciting new science that complements, but does not duplicate, NASA Earth Observing System (EOS).

The Vegetation Canopy Lidar (VCL) mission, led by Prof. Ralph Dubayah of the University of Maryland, College Park, will provide the first global inventory of the vertical structure of forest canopies across the Earth using a multibeam laser-ranging lidar system. Through demonstration flights from aircraft Dubayah has already demonstrated the ability of penetrating the vegetation canopy so that not only the distribution of tree top height can be determined but also the surface topography beneath the forest understory, even in thick rainforest environments.

The Gravity Recovery and Climate Experiment (GRACE), led by Prof. Byron Tapley of the University of Texas, Austin, employs a satellite-to-satellite laser tracking system between two spacecraft to measure the Earth's gravity field (geoid) and its time variability over

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five years. Such measurements of the Earth's geoid are crucial for accurate long-wavelength ocean circulation processes and to the transport of ocean heat from the equator to poles, as is measured by radar altimetry missions such as TOPEX/Poseidon and Geosat Follow-on Jason-1. GRACE involves significant international participation by co-principal investigator Dr. C. Reigber from GeoForschungs Zentrum (GFZ) in Potsdam, Germany.

In addition, a backup mission was selected in the event that one of the selected missions runs into cost, schedule, or technical difficulties. Called the Chemistry and Circulation Occultation Spectroscopy Mission (CCOSM) and led by Prof. Michael Prather of the University of California at Irvine, this mission is aimed at better understanding how atmospheric circulation controls the evolution of key trace gases, aerosols and pollutants over time. It is based on Fourier transform spectroscopy techniques and would measure limb emission and solar scattering and transmission during sunrise and sunset events.

The ESSP selections were made from a group of 12 proposals that were evaluated in the second phase of a rigorous, two-phased selection process that began less than eight months ago with the July 1996 release of the ESSP Announcement of Opportunity (AO). The original announcement generated 44 proposals which were subsequently evaluated on the basis of scientific merit.

The total mission lifecycle cost to NASA of VCL is $59.8 M, including launch vehicle, and will be launched in Spring 2000 from a Pegasus launch vehicle. GRACE has an innovative teaming arrangement with GFZ which includes the provision of mission operations and a Russian booster for a Spring 2001 launch, reducing the direct costs to NASA, which will be $85.9 M. Finally, NASA has set aside 10% of the annual budget for the ESSP program to support innovative data analysis and research investigations resulting from data acquired during these missions, funds which will be allocated later based on a rigorous peer review process following launch of these missions.

On February 6 President Clinton submitted his budget for fiscal year 1998 (which begins October 1, 1997). This budget includes $1.417B for Mission to Planet Earth. Furthermore, due in large part to efforts by the administration as well as both parties of Congress over the past summer, the proposed budget represents both balanced and sustainable funding for NASA over the next five years. The final budget must still await hearings in the House and Senate authorization and appropriations committees over the next 6 months.

Data gathering is continuing for a biennial review of MTPE that should be held in Spring 1997. This review is an important element in periodically assessing the MTPE program status and direction in response to increased scientific understanding, evolving technology, new opportunities in the commercial, international, and operational arenas, and budget constraints. This review will focus both on progress made in MTPE/EOS since the National Academy of Sciences' Board on Sustainable Development review in July 1995, and will further consider (i) balance in the research & development program between basic and applied research, airborne science, modeling, and global observations, (ii) implementation strategies and scientific priorities for EOS Chemistry-1, (iii) ground system architectures for operation of future MTPE/EOS missions after the early release of software needed to support TRMM and EOS AM-1, (iv) strategies for the insertion of new technology through programs such as the New Millennium Program (NMP) and the instrument incubator program, (v) plans and opportunities for international, interagency, and commercial partnerships both in space-based and validation activities, and (vi) strategies for implementation of NASA-led missions.

Finally, I am happy to report that ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer) and CERES (Clouds and the Earth's Radiant Energy System) have been delivered to Lockheed Martin Missiles and Space, King of Prussia, Pennsylvania, for integration on the AM-1 spacecraft. These are the first two of five instruments that will fly on AM-1, still scheduled for launch in June 1998.

**—Michael King**
EOS Senior Project Scientist

# Minutes of the EOSDIS Panel Meeting

— **David M. Glover** (david@plaid.whoi.edu), EOSDIS Panel Chair

A meeting of the IWG EOSDIS Panel was held at the Laboratory for Atmospheric and Space Physics (LASP) facility, University of Colorado, on February 12-14, 1997 to address some of the alternative suggestions being raised as solutions to the "EOSDIS problem." Since the announcement by Hughes of a slip in their delivery schedule for release A and the consequent cancellation of the TRMM portion of that release, a great deal of attention has been focused on the potential for downstream effects on release B. This meeting of the EOSDIS Panel was convened to better acquaint ourselves with the options now on the table prior to joining the rest of the IWG in San Diego.

This report covers a briefing from H.K. Ramapriyan on EOSDIS Status and Plans including the ESDIS backup plans for releases B.0 and B.1, an update on the current user/usage patterns at the DAACs with V.0, a discussion of the DAAC certification mechanism led by Betsy Edwards (GSFC, Code 170), a briefing on the biennial review from Skip Reber and Dolly Perkins (who chairs the EOSDIS Study Team for the biennial review), an update of the status of the Federation and in particular the status of the Working Prototype-Earth Science Information Partner (WP-ESIP) CAN, and a frank discussion of many of the suggested ways of dealing with the EOSDIS problem.

**ESDIS Replan Status**

Rama briefed us on how ESDIS has recovered from the initial slip and release A TRMM termination to bring ECS back in line to support AM-1/SAGE-III missions. ECS's Release A activities in support of TRMM have been assigned to the Goddard and Langley DAACs. The remainder of Release A (needed as a precursor to Release B) has been merged with Release B. By freeing the release A personnel to work on release B, converting a configured release A system (already undergoing integration) into a pre-release B test bed, and instigating a new system of metrics to oversee Hughes progress, ESDIS believes that the influence of the release A slip on release B can be minimized. Rama showed examples of metrics that are now being used to track progress weekly and to identify problem areas. The metric now being employed by ESDIS is a point system based on the total amount of work that could ever be done, the amount of work expected to be finished by a certain date, and the actual amount of work accomplished by that date for each task. In addition, a number of alternative time-buying options are being explored. In particular two backup-plan studies were conducted for supporting Landsat-7 and AM-1/SAGE-III missions. ECS remains the primary path for mission support, but these backup plans were to buy insurance to reduce the risk. The backup plans are limited, interim (up to six months) solutions. In early February a decision was made to go forward with the contingency data system for Landsat-7 with a system requirements walkthrough planned for early March. A decision on whether or not to continue was to be made at that time. In mid-February (as these minutes were in preparation) a decision was made not to continue the AM-1/SAGE-III and Landsat-7 backup activities. This decision was based on the lack of funds in the FY97 and FY98 overall EOSDIS budget and no real hope of augmentation of those budgets. Extracting the necessary funds from ECS was deemed to substantially increase the risk of a release B.0 delivery delay.†"

**Understanding EOSDIS and EOSDIS Costs**

Bruce Barkstrom provided us with an appraisal of the three key drivers of EOSDIS cost. EOSDIS must produce data, help users find data, and distribute that data. In order to produce the data EOSDIS must accept code from the data producers, compile and link it, accept directions from the data producers, and store the data when the run(s) is/are complete. Users may want three kinds of information from EOSDIS: the data themselves, subsets of the data, and information about the data (metadata). Distribution of data seems to fall into two categories: large data orders from a small fraction of the user community and moderate data orders from the rest of the users. The large data users

† Since then, substantially scaled-back "emergency" back-up plans have been initiated for AM-1/SAGE-III in accordance with the recommendations from the Science Working Group for the AM Project (SWAMP) and the EOSDIS Panel.

can and should be handled by media transfers, the remaining data requests can be handled with network deliveries. Bruce presented the distribution figures from the DAACs; it was surprising to see that they are already distributing 2.5 TB/month! Breakdown charts of the users that access the DAACs to obtain data reveal U.S. Education, U.S. Commerce, and foreign users lead the pack of data consumers. When it comes to finding the data there appear to be widely different points of view on the value of the metadata to do so. A discussion ensued regarding the merits of the current metadata model being employed.

### DAAC Certification

Betsy Edwards from Code 170 presented a review of the current plans for certifying the current DAACs. At the request of Code 170, the NRC's Committee on Geophysical and Environmental Data (CGED) has agreed to review the current DAACs. This committee has been around for 35 years and acts to review the World (and National) Data Centers in this country. However, the CGED recognizes that the DAAC situation is unique and has begun the review process with "scout" visits to the various DAACs to help the NRC better understand what DAACs are and what they do. The review criteria will be established in February 1997 (with input and agreement from DAACs and NASA). Site visits from the review panels will be held in March and April of 1997 and the CGED will generate a report deliverable to NASA by October 1, 1997. Codes 170 and Y will go over this report and make the final decision about certification. The NRC will only operate in a fact-finding/advisory role. Edwards stated very clearly that this was not a DAAC hunt: the NRC will review; NASA will certify.

### Biennial Review

Skip Reber began the presentation of what the biennial review is all about. The idea for such a review grew out of Charlie Kennel's idea that NASA could gain a great deal of control over the MTPE-review process if it set up such a mechanism, rather than wait for Congress (or someone else) to instigate a review. There was no implicit or explicit agreement from an organization such as the NRC to replace its reviews with this internally generated review. Nevertheless, the concept of a biennial review has grown since Kennel's days, and it is now being presented to the world as the reinventing of MTPE. Reber pointed out that some requirements of EOSDIS are now in jeopardy because of this. Another discussion about the EOSDIS requirements ensued and we started down a road this panel has been down before. A draft list of high-level requirements for EOSDIS was floated before the panel until it was pointed out such lists are always disconnected from their associated costs. No matter how good our intentions, a list of high-level requirements (that everyone could buy into) never gives us the satisfaction we are looking for. As soon as someone suggests cutting one of these high-level requirements we immediately see that their real value is impossible to calculate because the price of EOSDIS goes down only a little bit, or not at all. This is because of the intertangled nature of the functionalities and requirements of EOSDIS. Cutting a requirement frequently does little to bring down the cost of the DIS because the functionalities that support the deleted requirement also support other requirements that have not been deleted and little or no cost savings is had. Of course this is not unique to EOSDIS—any large project has this sort of problem. However, this line of reasoning is something of a red herring itself. The revisit of requirements is NOT to revisit ESDIS' current implementation of those requirements. The revisit should be the background for FUTURE implementations, beyond the PM-1 mission. This is the sort of thing that the EOSDIS Study Team, led by Dolly Perkins (Code 510), is charged with doing as part of the biennial review.

Skip Reber presented a list of ten simple goals that the EOSDIS Panel endorses as a reasonable long-range outlook for EOSDIS. They are, in no particular order:

◊ (24)33 measurements: process, archive, and distribute data from a diverse set of environmental measurements, including on the order of one thousand parameters.

◊ Large data volume: support of archival, access, and distribution of very large data holdings. This implies careful and precise documentation of information about the data to facilitate efficient searches for specific data sets and subsets.

◊ Reprocessing: support reprocessing of these data sets one or more times as the investigators learn more about their measurements. This implies a large processing capability and careful adherence to traceability requirements and configuration management.

◊ 15 year data set: support archiving and distribution of long-term monitoring data sets. This implies configuration management, refresh or upgrade of media, and an appropriate data management system. This also implies evolvability of the system over time.

◊ Inter-instrument dependencies: support processing of data from instruments where one or more instruments may require the use of data from one or more other instruments in its (their) processing. Support interoperability among data centers.

◊ Inter-disciplinary studies: support access and distribution of diverse types of data to a wide range of scientists who individually require several of these data types. Ease of use and transparency are desired. This could imply common access processes and common formats.

◊ Diverse user communities: support access and distribution of diverse types of data to a wide range of users. This implies careful and precise documentation of information about the data to facilitate efficient searches for specific data sets and subsets, and encouragement of third-party value-added suppliers to service the less scientific users.

◊ Access to existing and external data sets: need to be able to migrate existing data (e.g., Version 0) and data external to EOS (e.g., NMC) into EOSDIS.

◊ Concept of "Standard" Data Products: A subset of the data obtained is to be processed on a routine basis shortly after acquisition.

◊ No "Nimbus 7" Mode: Data shall be available to a wide scientific community on a reasonably short time scale after they are produced, to facilitate validation and use.

Dolly Perkins (Code 510) followed Reber to talk to us about the EOSDIS Study Team she chairs as part of the biennial review process. Her charge is to specifically look at EOSDIS in the post-release-B time frame. This roughly translates into DIS for MTPE in the year 2000 and beyond. What sort of DIS should we have? Should we continue with the evolutionary development of ECS until a Federation is in place? This study will provide input into the biennial review process to suggest new strategies for MTPE. In this context a discussion of the WP-ESIPs came up. Are the WP-ESIPs still being considered an experiment? Or, in other words, will the WP-ESIPs be allowed to fail? It was restated that the position of this panel has always been that unless allowed to fail the experiment of creating WP-ESIPs will be a waste of time and resources.

**Federation Status**

The EOSDIS biennial review study team discussion was followed by an update on the status of the EOSDIS Federation. After giving a quick review of the NRC report from La Jolla (1995), Betsy Edwards gave a review of the MTPE concept of a data federation with the goal of evolving a process by which Earth science data will be easy to locate, access, and use. Another goal of the Federation is to increase the involvement of the scientific community in the EOSDIS enterprise as a whole. NASA is considering three types of ESIPs: type 1 will handle the standard data products with an emphasis on reliability; type 2 will produce scientific research products with an emphasis on creativity; and type 3 will produce data products that extend beyond global change research with an emphasis on commercial applications. A Cooperative Agreement Notice (CAN) for types 2 and 3 will be issued in early 1997, and the DAACs will be certified during FY97 forming two federations until approximately the year 2000. One issue that still remains to be addressed in detail is how will the Federation be governed? Working out this issue will be one of the first tasks of the working prototype federation of types 2 and 3 ESIPs. Selection of these ESIPs is still planned for July 1997, but the writing of the type 2 CAN is breaking new ground for NASA and may affect the type 3 CAN. It is highly desirable to have both CANs released at the same time so that the Federation startup activities can be synchronous.

**Concerns and Recommendations**

Those present at the meeting voted that, in our view, the Version 0 DAACs' user access statistics (presented by Bruce Barkstrom) are very good news and show strong support for MTPE science and data. The IWG should take note that these statistics point to a use of, and dependence on, EOSDIS that seems to get little fanfare.

It was noted, by the chair, that a fair amount of functionality is being delayed until release B.1. Although there may be little other alternative, given the current funding envelope, I am concerned that those functions are at risk of being dropped completely from the

EOSDIS program. This is particularly true for functions that are considered to be outside the limited requirements of defined scientific and application users. If carried to a logical conclusion, such restrictions would amount to a giant step backwards for NASA when it comes to handling data collected at the taxpayer's expense.

We think that the backup plans produced by the ESDIS project are a good and prudent thing. We suggest that the instrument teams (along with their DAAC partners of choice) begin exploring backup options that go beyond ESDIS's interim six-month period, just in case B.0 is not ready at launch. This is because the critical and non-negotiable requirements on EOSDIS and the networks stem from the fact that validated scientific data products require a substantial amount of careful examination and rework. This fact requires access to data by the data producers, either in the form of adequate network bandwidth or media deliveries that are likely to be in excess of the 2X expectations that the Project has used. Because of the concern over production and distribution capacity limitations of the early B.0 release, it was the consensus of the data producers present at the meeting that they would be uncomfortable proceeding without implementing the backup capability they have recommended to the Project. Indeed, these data producers expect a period of six months or more of "configuration tuning" of the delivered early releases of the ECS system. In other words, the science software may run satisfactorily at the SCFs, but the teams are concerned that as the complexity of the ECS system becomes apparent, they cannot support production of good data and debug the system at the same time. To these teams, it appears there is a large risk that enough of the bugs will not have been worked out of a system that is delivered shortly before launch to make production feasible. The EOSDIS Panel is aware of the recent decision not to support the AM-1/SAGE-III backup study any farther and the explicit statement by the ESDIS project to, essentially, "bet the farm" on release B.0. A prudent instrument team PI would be exploring other options, regardless of the commitment of funds from ESDIS.

Since the best bandwidth ever mentioned for ECS is the canonical 2X, it is generally felt that most instrument teams are likely to want to get at least one copy of the Level-1 (calibrated) data. Where does this leave us in terms of network access to the rest of the Earth science community?

There is tension between at least two communities in the EOSDIS world: the instrument teams and the database engineers. In order to develop a system that is efficient in its searches the database engineers have created a large, all-encompassing list of metadata so that any request from any users can be handled quickly. However, the instrument teams feel burdened to extract even 30% of this total list from their data at a time when they are very busy finalizing production code, etc. The implication is that there are a number of metadata items requested for all data product granules that don't always make sense for a particular data product.

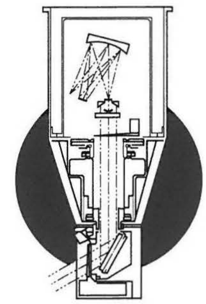
We recommend that a metadata workshop be held or better yet a series of metadata workshops. The users and the implementers of the metadata need to be brought together for an open exchange of ideas. Currently the "read DID-311" advice to instrument teams by the ECS folks is not helping. We suggest that at these workshops the required metadata for each data product be examined to remove items that make no sense. The various working groups should also be included. The Data Science Working Group (DSWG), Data Management Working Group (DMWG), and Client Design Working Group (CDWG) are too fractured; perhaps they should be pulled together into one umbrella organization for coordination.

Given that we cannot seem to put a price tag on specific requirements (regardless of the level) of EOSDIS, how can we attach a sense of worth to aspects of EOSDIS so that we can be comfortable with the expense of building our data system?

After serving the EOSDIS efforts handsomely, the Ad Hoc Working Group for Production (AHWGP) and Ad Hoc Working Group for Consumers (AHWGC) have run their course and probably should be disbanded. Kudos to the chairs, Barkstrom, Emery, Emmett, and Ramapriyan for their hard work pulling together difficult-to-obtain data for the ECS effort and ESDIS project office.

It is recommended that either the EOSDIS Panel elect members to join the nascent Federation after the CANs have been awarded to the type 2 and 3 ESIPs or the type 2 and 3 ESIP PIs join the EOSDIS Panel—to ensure the passing along of the corporate memory of where we've been during the last 8 years.

# Stratospheric Aerosol and Gas Experiment III (SAGE III)



— **Sandra Smalley** (s.e.smalley@larc.nasa.gov), SAGE Science Manager, Aerosol Research Branch, NASA Langley Research Center

On August 27, 1996, a Science Team meeting for the Stratospheric Aerosol and Gas Experiment (SAGE) III was conducted at the National Oceanic and Atmospheric Administration (NOAA) facilities in Boulder, Colorado. The objective of this science team meeting was primarily to discuss the Algorithm Theoretical Basis Document (ATBD) development status. Other topics included an explanation of the revised roles of the Principal Investigator and the Associate Principal Investigator, a review of the instrument development status, and the validation plan.

M. Patrick McCormick opened the Science Team meeting with an overview of his current status. McCormick recently retired from NASA Langley Research Center and is now a professor in the Physics Department at Hampton University, in Hampton, Virginia. Currently, McCormick is attempting to change the SAGE III Principal Investigator position to his current position at Hampton University. In this way, he will maintain leadership and advisory roles from a science standpoint. William P. Chu, NASA Langley Research Center (LaRC), will now become the Associate Principal Investigator. In this role, Chu will speak for resources associated with NASA's sponsorship of the Science Team and provide additional management of the team.

In addition, McCormick reviewed the status of items from the last meeting. The ATBDs are currently on schedule for a November 1996 delivery to the EOS Senior Project Scientist. In addition, the Data Validation Plan is also on schedule for delivery to EOS. These products will undergo several reviews prior to their release.

Lemuel E. Mauldin, SAGE III Project Manager, presented the status of instrument development. The SAGE III Critical Design Review was held on August 28 and 29, 1996, with no major issues open in the development of the instrument. With the successful completion of this review, the SAGE III project transitions from a design phase to a production phase. Mauldin reported that the SAGE III Project is on-schedule and under-budget.

Michael Cisewski, SAGE III Mission Operations Manager, gave an overview of the SAGE III Mission Operations with respect to the Meteor-3M Mission. Cisewski provided a schedule of near-term events with respect to mission operations planning.

Chauncey Uphoff, Orbit Mechanics Engineer, Fortune-8, Inc., gave an overview of the SPOT-5 Orbit Mechanics Analysis he has been performing with respect to the SAGE III/SPOT-5 Phase A study. This study is for both the SAGE III and SPOT-5 projects to study the feasibility of flying SAGE III on the SPOT-5 spacecraft. The 10:30 p.m. orbit limits the number of lunar encounters for SAGE III. It will have only 50-60% of the lunar encounters for the Meteor-3M mission. Most of the lunar encounters found on SPOT-5 will occur during the spring.

Chu gave an overview of the Joint Russian/U.S. Science Plan. This plan is a result of a joint agreement made under the Mission to Planet Earth Joint Working Group. The plan is to detail Russian participation in SAGE III science. Possible participation lies in the areas of scientific investigation, algorithm development, mission operations, and data validation.

Joseph Zawodny, LaRC, reported on his attendance at the EOS Payload Panel Meeting. This meeting concentrated on a framework in which an instrument can demonstrate its needs (for instance, to fly with other complementary instruments). With respect to the health of the SAGE Program, Zawodny reported that SAGE's international relationships and cooperations are helpful to program longevity. In addition, SAGE will definitely fly on the International Space Station, though the 2001 date may change. Ideas for helping the SAGE program include focusing on technology advances for SAGE III and on the new way of doing business. There is a new stress on infusing new technology. In addition, Zawodny reported that there was some discussion of breaking up the CHEM spacecraft into three platforms, and that the time line of EOS beyond CHEM-1 is being looked at. Things will change significantly. Overall, the meeting produced positive results for the future of SAGE III.

Zawodny and Gary Hansen, STC/LaRC, then reported on the status of the Test Occultation Instrument (TOI), which consists of the SAGE III spectrometer/telescope and associated electronics. This unit will be used for testing and instrument performance verification and to verify Ball test data. The TOI will assist in algorithm development. In addition, it will transition to a ground-based radiometer instrument for data validation.

Hansen has prepared LaRC for acceptance of the TOI hardware. The date of delivery is dependent on selection of the desired telescope primary mirror, as the mirror which is currently in the TOI is not the same design as that found in the flight model. However, it may be acceptable for the desired use. Capabilities and features of the TOI include transportability and rastering. Laboratory measurements that can be taken in order to characterize the instrument are (i) scattered light analysis, (ii) image mapping of the solar disk and lunar disk, and (iii) full spectral images of the moon in order to gain real data for the algorithms. McCormick requested that Zawodny put together a list of capabilities of the TOI.

Michael Rowland, Science Applications International Corporation, gave an overview of the SAGE III home page, which was recently opened to the public. The URL of the home page is http://arbs8.larc.nasa.gov/sage3/sage3.html.

Chu presented the status of the ATBDs, which have been revised with suggestions made by Science Team members. He reported that the electronic versions of these documents are available for download. There are outstanding issues regarding clouds and inhomogeneity. A significant point that should be considered is that these documents are usually completed three years prior to launch. However, for the Meteor-3M launch there will only be one-and-a-half years prior to launch. This fact will lead to comments and changes that can be made to the documents later. Chu requested a list of potential reviewers for these documents.

David Woods and Chip Trepte presented the validation status. Woods has investigated the use of resources for validation, and provided an overview of available resources. Trepte discussed budget issues relative to validation. Some potential solutions for aircraft-based validation include (i) attempting to have other experiments dovetail with SAGE validation for flight time and (ii) using NCAR aircraft with support from the university community. Important elements to validate include refractive index, chemistry changes, size distribution and algorithms/line of sight. A discussion was held with regard to the importance of validating measurements made in polar regions during active dynamical periods (the most expensive validation element). Options for validation of other species include: aerosols/water vapor—balloons from Fairbanks; $NO_3$—TOI; and OClO—other instruments in operation simultaneously. Because SAGE II history already exists for most species, it may be possible to do one validation per fiscal year. The decision on this matter will be left open until all avenues are researched.

Eric P. Shettle, Naval Research Laboratory in Washington, DC, discussed his work on the spectroscopic assessments for gaseous constituent retrievals in the visible and ultraviolet spectral regions.

Benjamin M. Herman, University of Arizona, gave a presentation regarding temperature measurements using SAGE II data. Looking at the sun, one can make an estimate of the refractive bending angle of the rays. Using the index of refraction, which is dependent on density, one can get the density profile. From the density profile, one can derive the pressure profile and use the equation of state to obtain the temperature profile. The process should start at the highest level at which reasonable data can be obtained (50 km). A problem is that the pointing angle of the mirror is not known to the accuracy or precision needed. Averages must be taken of the downscan and upscan, which produce many uncertainties. Another problem is that the angular dimension of the sun is changing across the data set on the order of tenths of minutes. Mike Cisewski reported that SAGE III will have more accurate scan mirror control and spacecraft attitude information as well as an independent measure of temperature.

Zawodny gave a status of the reprocessing of SAGE II data with respect to lessons learned. The current release of software is 5.93. Version 5.94 has been in process for a year. It contains a fix for thermal shock, which affects sunrise $NO_2$ data. This version can be made available immediately. Version 5.95 will improve the characteristics of 600-nm aerosol. A new set of coefficients was developed by Larry Thomason to increase the altitude range by 2-3 kilometers, with agreement to ozonesonde data during the peak of the Pinatubo period. There is no single set of linear coefficients which fits the theoretical data for the whole family of aerosol distributions. Therefore, a set of coefficients (non-linear versus linear) will be developed. The 5.96 version will address the degradation of $NO_2$ absorption data. The current version shows a 30% decrease, which may be corrected by modeling the change in wavelength and bandpass of the 448-nm channel. Version 5.97 will improve the tropospheric ozone retrievals by correcting for some water vapor absorption at 600 nm via unification of the water vapor processing with the processing for retrieval of the other species. (It is currently processed separately ignoring the mutual interference between ozone and water vapor.) This release will probably be available by the beginning of 1997. Version 6 transmission will show a finer altitude grid, an adjustment to edge times, better size-of-disk estimates, and a spectral dependence of refraction . Efforts to look at SAGE I data with SAGE II methods (after version 6 release) will result in many lessons learned.

Zawodny also gave a summary of the SPARC meeting. SAGE went first with a report of lessons learned. Later, the balloon sounding method was discussed by the scientists to explain problems with ozonesonde profiles, which show large pump efficiency problems at high altitude. This can introduce large trends in data. SAGE II is the only global data set that can show trends in the lower stratosphere and upper troposphere with high (1 km) vertical resolution.

David A. Rogers, Ball Aerospace, SAGE III Project Manager, hosted a tour of the Ball facilities in Boulder, including progress made on SAGE III test equipment, software, and hardware.

## EDUCATION RESOURCES ON THE INTERNET

***NASA's Educational Technology Program — http://www.hq.nasa.gov/office/mtpe/edreports.html***
This program targets two of the four Focus Areas specified by the National Science and Technology Council, Subcommittee on Research and Development for Education and Training: (1) Development of High-Quality, Affordable Learning Tools and Environments, and (2) Demonstrations of Innovative Technology and Networking Applications.

***The Observatorium - Education Center — http://observe.ivv.nasa.gov/observe/techpark/edu/edu.html***
This site provides useful links to many NASA-related programs. The programs are organized by grade level, topic, and outreach programs, and include Aeronautics, Atmosphere, Land, Space, and Water.

***The Learning Web at the U.S. Geological Survey — http://www.usgs.gov/education/learnweb/index.html***
This site provides educational information and resources for use within the classroom. The subjects encompass lesson plans in Global Change and other areas in Earth Science education.

***Oceanography from the Space Shuttle — http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/shuttle_oceanography_web/oss_cover.html***
An out-of-print, 200-page limited edition pictorial survey of oceanic phenomena visible to the naked eye from space. A joint project of the University Corporation for Atmospheric Research and the Office of Naval Research, United States Navy, placed on the World Wide Web by the NASA/Goddard DAAC.

***JPL SIR-C Education Program — http://southport.jpl.nasa.gov/education.html***

# The International Land-Surface Temperature Workshop

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## Introduction

The International Land-Surface Temperature Workshop was held on September 17-19, 1996, at the University of California at Santa Barbara. Jeff Dozier, Dean of the UCSB School of Environmental Science & Management, welcomed the participants. Twenty-five participants from the USA, France, Australia, and Japan attended the workshop. Twenty presentations were followed by two discussion sessions. It was a successful and productive workshop. The important findings of the workshop are outlined below together with the recommendations for further actions.

## Workshop Objectives

The workshop was part of a continuing effort to maintain contact among members of the EOS community that are concerned with the improvement of land-surface temperature (LST) algorithms, the definition of procedures for validation of LST, and the identification of the sources and the magnitude of measurement uncertainties. The specific goals of the workshop were to clarify the present state of the art in LST estimation from spaceborne sensors and to identify future directions, including issues requiring further research effort. A subsidiary goal was to establish a closer relationship between LST algorithm designers and the LST user community.

## Overview of Scientific Presentations

The importance of accurately determining LST to support an improved understanding of land-surface processes, including land-surface forcing, and the correlation of LST with the enhanced greenhouse effect, were some of the issues identified by Z. Wan in an overview paper titled "Challenges and opportunities for LST." The prospect of suitable data sets for LST research is soon to be enhanced by the impressive range of on-orbit sensors to be launched over the next few years. To advance the science, algorithm developers need to improve validation programs, collaborate more in the development and refinement of LST and land-surface emissivity (LSE) algorithms, undertake comprehensive and coordinated field campaigns, and forge closer relationships with General Circulation Model (GCM) scientists.

The technical aspects of the MODIS instrument design, and key role that it plays in the provision of accurately calibrated shortwave (SWIR) and longwave (LWIR) infrared radiances for LST research, were reviewed by C. Schueler of SBRS (Hughes) in a paper, "Technologies for temperature sensing from space." The specific algorithm proposed for application to MODIS to derive LST was presented in a paper, "MODIS generalized split-window LST algorithm," by Z. Wan and J. Dozier, who outlined the theoretical basis of the approach, the sensitivity and error analysis, and the results from validation campaigns conducted at Railroad Valley Playa, Nevada, with the MODIS Airborne Simulator (MAS). The algorithm assumed that the band emissivities for the surface under investigation were well characterized. According to simulations in wide ranges of atmospheric and surface conditions, the rms errors in retrieved LST were typically 0.7 K. A follow-on paper, "MODIS day/night LST algorithm for retrieving land-surface temperature and emissivity," by Z. Wan and Z-L. Li, proposed a MODIS day/night algorithm that has the ability to reduce the atmospheric effects caused by the uncertainties in atmospheric temperature and water vapor profiles in the process of simultaneous retrieval of surface temperature and band emissivities. Validation data over Railroad Valley Playa, Nevada, showed retrievals from MAS had an accuracy of 1K, but there is a significant difference between the retrieved emissivities and those measured from samples in the laboratory. A paper titled, "Thermal infrared surface radiance and its validation," was presented by F. Palluconi and addressed the role of ASTER in surface radiance measurement. The approach adopted applied radiative transfer methods to determine the radiance at the satellite. A sensitivity study concerning the impact of atmospheric temperature, water vapor, ozone, and visibility on the radiance was presented. Also described was a validation program which was conducted over instrumented lakes in California and Nevada.

A. Gillespie, T. Matsunaga, S. Rokugawa, and S. Hook, in a paper titled, "Temperature and emissivity separation from Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) images," provided a description of a temperature and emissivity separation algorithm (TES) ultimately designed for application to ASTER. The approach involved an iterative scheme to remove the effect of downwelling sky irradiance reflected by the surface. From the validation data presented, it appeared that the scheme worked well over a variety of land-surface-cover types. Further, the derived spectral variation in emissivity compared well with *in situ* data acquired at the Railroad Valley Playa, Nevada, test site.

D. Ellement, M. Lynch, B. White, and I. Tapley presented "Land surface temperature estimation with AVHRR and numerical models applied to Western Australian field sites." With preset emissivities, split-window LST algorithms were developed that are accurate to about 1 K over several instrumented test sites. A model of the diurnal LST cycle was being evaluated and applied to a remote region in the north of Western Australia. T. Schmugge and C. Coll's paper, "Application of the TES algorithm to TIMS data from HAPEX-Sahel," described the application of the TES scheme to Thermal Infrared Multispectral Scanner (TIMS) imagery. The emissivity normalization derivation performed well but required a reasonably good first guess; for the emissivity min-max difference approach, the performance was comparable, but there was much less sensitivity to the first guess. Some difficulty was encountered for application to gray bodies.

A paper by M. Moriyama, "Error analysis of ASTER T/E Separation," described an implicit scheme which employed the covariance of the observations to estimate uncertainty in the retrieved surface variables. "Simultaneous determination of atmospheric correction parameters, LST and spectral emissivity from TIR multispectral data over land," by H. Tonooka used a multi-pixel method, based on scene modeling, to estimate sky radiance and the surface parameters. The scheme was applied to TIMS data, and the performance and limitations were discussed.

The important information content in high-spectral-resolution infrared radiometry was the key point of the paper, "Land surface temperature and emissivity estimation with high spectral/high spatial resolution sensors," by H. E. Revercomb, M. J. Lynch , L. E. Gumley, K. I. Strabala, and P. F. W. van Delst. High-spectral-resolution radiometry allowed the sampling of spectral regions in between atmospheric emission lines, where the atmosphere is highly transparent, and the downwelling thermal radiance is negligibly small. This approach permits a separation of the surface temperature and the spectral emissivity. "Validating remotely sensed land surface temperatures for surface radiation studies," by A. J. Prata, R. P. Cechet, I. F. Grant, and G. F. Rutter, outlined an impressive program that continued the development of a network of ground-truthing stations spanning the Australian continent designed to support validation and modeling studies using satellite data. The comprehensive data sets being acquired at existing sites were described. Finally, the additional information gained using the Along-Track Scanning Radiometer (ATSR) to evaluate LST was discussed and illustrated with examples using ATSR imagery over an Australian field site. S. N. Goward, R. O. Dubayah, K. P. Czajkowski, A. Waltz, and S. Liang, in a paper, "Validation of the split-window land surface temperature algorithms," outlined activities in the AVHRR Pathfinder program and the studies that they were undertaking in global primary production and modeling the surface energy budget. They compared the results of an analysis of the performance of 12 split-window algorithms applied to data sets from BOREAS, FIFE, and HAPEX-Sahel and undertook an estimation of the sources of error in the resulting LST products. The paper concluded with a discussion of the role of spatial scaling of data sets when statistics derived from a sensor of one spatial scale are compared with those derived from a sensor operating at a different spatial sampling scale (e.g., AVHRR and Landsat TM).

"MODIS and MAS LST field campaigns," by W. Snyder, Z. Wan, Y. Zhang, and Y. Feng, described field work conducted at Railroad Valley Playa on June 4, 1996, and outlined activities planned for a further BOREAS experiment later in 1996. These field campaigns were part of preparations for validation underflights of MODIS with MAS. Their error analysis showed that contributions of 0.3 K, 1.0 K, and 0.3 K were assignable to temporal, spatial, and calibration sources, respectively, giving an accumulated error of 1.09 K. The analysis of the error budget for vicarious calibration of TIR sensors was addressed in a paper, "Selecting appropriate sites for calibration of TIR sensors," by Z . Wan. Associated modeling studies, which assumed realistic uncertainties in the knowledge of the atmospheric state (3 K in temperature, 30% in water vapor profiles, 10% in water vapor absorption coefficients), were presented. For successful vicarious calibration, the sources of uncertainties (radiative transfer ~0.2%, surface emissivity ~0.003, measured LST ~0.88%, calculated radiances at the top of the atmosphere ~0.37%, ~0.71% and ~0.65%, for MODIS bands 29, 31, and 32 respectively) were expected to produce radiance rms errors of 1.01%, 0.79%, and 0.74% in these three MODIS TIR bands. A dry region in midwestern Tibet, and possibly in Bolivia, is the area where it is expected that these vicarious calibration accuracy requirements could be achieved.

The sole paper on the role of microwave radiometry, "Surface temperature estimation over land using satellite microwave radiometry," was presented by E. G. Njoku. After reviewing the key issues of concern in surface sensing (including surface soil moisture, soil/vegetation temperature, surface reflectance, vegetation canopy opacity and fractional cover, atmospheric opacity and mean temperature, and polarization), the performance of regression and non-linear iterative retrieval methods for temperature were presented. For a large simulated data set, with multichannel measurements and homogeneous conditions, these two methods can retrieve surface temperatures with RMS errors of 2.1 K and 0.4 K, respectively, for assumed radiometric noise of 0.2 K. However, the effects of modeling error and sub-pixel heterogeneity can be expected to increase the retrieval error significantly.

R. Dickinson, M. Jin, and X. Zeng, in a paper titled, "A dataset of land surface temperature diurnal cycle from MODIS data and CCM/BATS," and a related presentation by X. Zeng and R. E. Dickinson titled, "How to use skin temperature in land surface modeling—the consideration of surface sublayer," described the coupling of satellite skin temperature with the NCAR Community Circulation Model (CCM), coupled with the Biosphere-Atmosphere Transfer Scheme (BATS) over various land-cover classes in the model. The performance of the model-estimated skin temperature for the FIFE data set (July 1987) was presented. The measurement error in skin temperature ratioed to the skin - air temperature difference was identified as a key requirement for accurate model performance, including flux estimation.

"TIR BRDF measurements and modeling," by W. Snyder and Z. Wan, outlined laboratory facilities suitable for making measurements on samples collected in the field. The importance of translating the laboratory measurements on components to MODIS scene parameters was illustrated with a discussion of BRDF kernels and emissivity anisotropy as a function of zenith angle. A related paper by Y. Feng, Y. Zhang, and Z. Wan, "Measurement of the thermal infrared spectral emissivity of foliage," described improvements made to laboratory instrumentation and measurement procedures. The data were recorded over the 3-14 μm range, but the band-averaged emissivities of vegetation canopies, for MODIS bands 31 and 32, showed that expected scene emissivities will vary over a very narrow range.

The meeting concluded with two review sessions chaired by S. N. Goward and F. Becker. The conclusions and recommendations are summarized below.

**Findings**

The prime task of the LST algorithms is to accurately correct both the atmospheric and emissivity effects in the TIR data for recovering LST. For land covers with high and stable emissivities, such as lake surfaces, snow, ice, and vegetation, split-window LST methods can be used to retrieve LST with surface emissivities estimated from ancillary information or prior knowledge. The coefficients of the split-window algorithm are derived from model simulations or field measurements conducted under certain atmospheric conditions. In high-humidity conditions the accuracy of split-window methods can be improved by adjusting these coefficients based on viewing angle and external assessment of the ranges of the atmospheric water vapor and temperature from satellite sounding, radiosonde, or meteorological analysis. Vegetation has a high value of, and little angular variation in, its emissivity in the split-window range (10-13 μm) because the component emissivity of vegetation is already high and is increased further by its structural properties. In semi-arid and arid regions, the surface emissivity varies over a wide range. This can result in a significant error in LST retrieved by the split-window method.

Several multi-band and/or multi-temporal methods have been developed for retrieving surface temperature and emissivity simultaneously. These methods utilize the special capabilities of specific sensors in remote sensing of the surface TIR status. For example, ASTER has five bands in the 8-12 μm range, MODIS has three bands in the 3.5-4.2 μm range and four bands in the 8-13.5 μm range, and the High resolution Interferometer Sounder (HIS) and Atmospheric Emitted Radiance Interferometer (AERI) provide high-spectral-resolution interferometric data in the 590-2750 $cm^{-1}$ range. The benefit of high spectral resolution of the latter sensors does permit a separation of the reflected atmospheric downwelling radiance from the surface-emitted radiance because the atmospheric emission line structure is resolved. This will be a benefit for validation, but it will be some time before this capability exists on orbit. With the advances in TIR sensor technology and in LST algorithms, and with the synergism between LST products generated from data of different satellite sensors with mixed characteristics in spatial, temporal, and spectral resolutions, it is possible to provide LST products for global and regional studies.

It is essential to make comprehensive error and sensitivity analyses of LST algorithms over wide ranges of atmospheric and surface conditions. A common source of error occurs when the resampling or mapping is made to obtain LST values at geolocated grids from the LST field that is retrieved from airborne or satellite data by whatever LST algorithms. In most applications, LST values are required at geolocated grids for temporal analysis and for uses combined with other data. The size of this error depends on the gradient in the retrieved LST field and it may be significantly large near boundary areas. In such areas, mis-registration of day and night data would increase the error of the MODIS day/night LST algorithm. Numerical simulations of the mis-registration in areas where pixels are mixed with two components with different emissivities and at different temperatures show that the MODIS day/night LST algorithm still works well (the RMS error in retrieved LST values over wide ranges of conditions is smaller than or near 1K) as long as the uncertainty in registration does not exceed 20 percent. Therefore, it is proposed to use the MODIS day/night LST algorithm to retrieve surface temperatures and band emissivities initially at 5-km resolution (the resolution used in the MODIS product of atmospheric temperature and water vapor profiles is five by five 1-km pixels).

A clearer understanding of the applications of LST is needed. For instance, the LST accuracy needed in climate models is not a constant but a function of the surface-to-air temperature difference. More study is required regarding the relation between the LST retrieved from TIR data and the LST and the lower boundary fluxes in climate models. Also, spatial scaling plays an important role in global climate modeling. Study is ongoing as to how LST scales and on climate modeling. Further, polar satellite LST provides 'snapshots' during the diurnal cycle that must be incorporated into climate modeling.

There is a need for more-conclusive *in situ* validation and accurate field measurement data that address sampling and instrumentation issues properly. Sampling a dynamic and spatial-varying, view-angle - dependent temperature field is often a dominant source of error. We need to consider combined use of radiometric and kinetic surface sensors and their placement. It is obvious that accurate field validation of LST can be made only over large flat uniform test sites and that comprehensive numerical simulations are needed to validate the inherent capability of LST algorithms in dealing with pixels mixed by components with different emissivities and at different temperatures. Significant improvement would result from the use of airborne sounders that are nadir-looking coincident with a scanner. There is also a need for long-term sites to establish accuracy under varying conditions and to provide data to a larger community.

More attention is needed for cirrus clouds and aerosols. For instance, the capability of cirrus detection at night may be questionable. Although aerosols play only a small role under normal conditions, there are certain areas with regularly high aerosol values that will bias the retrieved LST. The aerosol parameters in most atmospheric transmittance models may not be satisfactory and may require improvement via controlled field experiments.

There is continued potential for new and better LST algorithms. These algorithms will motivate and follow the development of cheaper and better instruments—for instance, high-spectral- and high-temporal-resolution sensors. For self-contained algorithms, an increase in the number of bands will allow better estimates of the atmospheric characteristics and possibly reduce the sensitivity to land-surface spectral emissivity if the signal-to-noise ratio of observation data is large enough.

Improvements for external methods will consist of the incorporation of assimilation data over time. Also, it is expected that sounder data will become more common and more accurate. This will provide the atmospheric profiles of temperature and water vapor needed for LST recovery. Passive microwave instruments provide a valuable, independent assessment to incorporate into LST algorithms. But it is important to understand the physical difference between the surface "skin" temperature measured by TIR sensors and microwave-measured temperature in real applications. The accuracy of LST estimated from microwave data is limited by the uncertainties in surface emissivity, which is affected by surface moisture variations. This would be improved with longer wavelength channels in future instruments.

The accuracy and role of geostationary sensors for providing higher temporal sampling of land temperature should be investigated. Such sensors offer a higher probability of achieving cloud-free conditions for a given location and also would provide data sets at a time more appropriate for model assimilation.

**Recommendations**

1. Make intercomparisons of different LST algorithms in their accuracy and sensitivity with real data in well-characterized surface conditions, and with numerical simulations in wide ranges of atmospheric and surface conditions.

2. Study the dependence of LST on solar and view angles, and study their impact on LST applications through *in situ* measurements and modeling.

3. Enhance the relation between land-surface temperature/emissivity and atmospheric profile products.

4. Land-surface temperature currently is an output of numerical models, but the temperature normally introduced in models is an aerodynamic temperature which cannot be measured from space. It would be therefore important to improve our knowledge on the relationships between the radiative and the aerodynamic temperatures so that LST measured from space can be used to validate the model outputs. Encouragement should be given for the conduct of numerical simulation experiments that assimilate LST measured from space and determine the level of impact on the forecast.

5. Conduct a field campaign workshop to continue the study of the requirements and implementation of field LST validation.

6. Conduct an air/satellite field validation campaign using a combination of high-spectral- and high-spatial-resolution airborne sensors as well as such sensors on polar and geostationary satellites. Diagnose the techniques for validation with a relatively easy target in a low-humidity atmosphere. Translate these to more-critical high-humidity conditions in later experiments. Examine the viability of TIR vicarious calibration.

7. Re-examine the optimal bands for multi-band retrieval of LST for future instruments.

8. There is a need to establish a set of permanently instrumented field sites so that algorithms can be tested over the full range of meteorological and surface conditions that occur at a given location.

# EOS Radiometric Measurement Comparisons at NEC Corporation and Mitsubishi Electric Corporation

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The second National Aeronautics and Space Administration (NASA)/National Institute of Standards and Technology (NIST) Earth Observing System (EOS)-sponsored spectral radiometric measurement comparison was conducted at NEC Corporation in Yokohama, Japan, and at the Mitsubishi Electric Corporation in Kamakura, Japan, November 5-15, 1996.

Radiance measurements were made by several participants on two integrating sphere sources. Participating institutions were Goddard Space Flight Center, NIST, the National Research Laboratory of Metrology (NRLM, Japan), and the University of Arizona (U of A). The two integrating sphere sources were used in the pre-flight radiance calibration of the Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) Visible and Near Infrared Radiometer (VNIR) and the ASTER ShortWave Infrared Radiometer (SWIR). These instruments, along with the ASTER Thermal Infrared Radiometer (TIR), will be assembled onto the first EOS spacecraft, EOS AM-1, at Lockheed-Martin in Valley Forge, PA, in early 1997.

The measurement plan was coordinated by NRLM and the Japan Resources Observation System Organization (JAROS) with input from NIST and the EOS Project Science Office. Key issues to be addressed were similar to the first radiometric comparison experiment in August 1996 (Butler and Johnson 1996): measurement repeatability, evaluation of unknown systematic effects, and stability. Again, time constraints required that the number of sphere levels measured be a subset of those used during the calibration of the ASTER VNIR and SWIR.

The overall goals remained the same as at the first intercomparison: 1) compare the spectral radiance of the sphere sources as calibrated by the EOS instrument providers (i.e., NEC Corporation and Mitsubishi Electric Corporation) with that determined by NRLM and NIST using NRLM- and NIST-calibrated radiometers; 2) compare the spectral radiance determined by the participants from the other laboratories using the sphere sources as common targets; and 3) evaluate the findings in terms of measurement procedure and basic metrology.

Because the measurements at NEC were preceded by measurements by the same participants in February 1995 of the sphere source used to calibrate the ASTER VNIR (Sakuma *et al.* 1996), the results of the new measurements can be compared to the earlier work. Because NIST has not completed the EOS-sponsored portable radiometer for the spectral region required for the ASTER SWIR, the spectral radiance scale of the sphere source at Mitsubishi could not be compared to that determined by NIST.

At NEC, the 1-m diameter integrating sphere used in the radiometric calibration of the ASTER VNIR was measured at three different levels by four teams of researchers over a six-day interval. One level was measured on two different days. At Mitsubishi, the 1-m diameter integrating sphere used in the radiometric calibration of the ASTER SWIR was measured at four different levels by three teams of researchers over a four-day interval, and two levels were re-measured on different days.

At NEC, the participants included John Cooper from GSFC and Hughes STX Corporation, Carol Johnson from NIST, Stuart Biggar from the U of A, and Fumihiro Sakuma and Juntarou Ishii from NRLM. Participating instrumentation included the GSFC-EOS scanning single-grating monochromator measuring from 400 nm to 1100 nm, the NIST EOS Visible Transfer Radiometer (VXR), the U of A visible/near-infrared transfer radiometer, and three NRLM ASTER visible/near-infrared transfer radiometers.

With respect to the participating filter radiometers, the VXR has six image locations with separate interference filter/detectors at each location. The interference filters are narrow band (~10 nm). The U of A visible/near-infrared transfer radiometer uses a rotating filter wheel to alternately measure at selected wavelengths that correspond to those in the EOS Moderate-Resolution Imaging Spectroradiometer (MODIS), which is also scheduled for flight on the EOS AM-1 platform. The solid angle in the U of A transfer radiometer is determined by a pair of precision apertures that are separated by a fixed distance and located between the filter wheel and the detector system. The NRLM radiometers are separate units, each making measurements at or near particular ASTER bands. NEC calibrated the ASTER VNIR integrating sphere source from 400 nm to 1100 nm on October 28 and 29, 1996, using a variable temperature blackbody and a double grating monochromator. The radiance temperature of the blackbody was determined by comparison to a standard blackbody that is at the temperature of freezing copper.

Daily, a series of measurements was followed by the reporting of preliminary results. The typical measurement procedure was to turn on the ASTER VNIR sphere source to a given radiant level determined by the lamp voltages and the specific lamps illuminated, measure using the VXR, then measure using the other participants' radiometers, and then repeat the VXR measurement. In this manner, over the complete course of the comparison, the sphere was measured at the same level at least twice by NIST, and twice by all the participants for one sphere setting.

Koichi Suzuki of NEC adjusted the sphere lamp voltages according to NEC procedures, and an automated data acquisition system was used to record the voltage of the sphere lamps and the output of two monitor detectors. One monitor detector consisted of a small silicon photodiode mounted on the edge of the exit aperture of the sphere and the other monitor detector consisted of a radiation thermometer with a center wavelength of about 650 nm. The radiation thermometer measured the radiance at the center of the exit aperture along an optical axis that was about 45° from normal incidence.

One level was measured each day with all measurements taking place in the same clean room in Building 25 at NEC that had been used for the 1995 radiometric measurement comparison. However, for this comparison, the area around the integrating sphere had been enclosed with black curtains to shield the measurement area from sources of ambient light. The automation feature, the use of the monitor detectors, the construction of the dark area, and the calibration of the sphere over the broad spectral interval were recommended by NASA and NIST following the 1995 radiometric measurement comparison.

Preliminary results from the 1996 measurement comparison are very encouraging and indicate a scatter of 1% to 2% among the participating institutions and NEC.

The comparison participants packed their equipment during the afternoon of 11 November and traveled to Mitsubishi on 12 November. The equipment was unpacked and moved into the clean room before lunch, and measurements began in the afternoon. At Mitsubishi, the participating institutions, individuals, and instrumentation included GSFC (John Cooper), with a scanning single grating monochromator operated from 1200 nm to 2400 nm; the U of A (Paul Spyak and Stuart Biggar), with the U of A shortwave infrared transfer radiometer; and NRLM (Fumihiro Sakuma and Juntarou Ishi), with two ASTER shortwave infrared transfer radiometers. NIST (Carol Johnson) observed the measurements and documented the intercomparison. The design of the U of A shortwave infrared transfer radiometer is similar to the visible near-infrared instrument, except that a liquid-nitrogen-cooled indium antimonide (InSb) detector is used.

Radiance measurements were made on the ASTER SWIR sphere source on 12 to 15 November, with sessions for discussion of preliminary results interspersed among the measurement intervals. Mitsubishi attempted to calibrate the ASTER SWIR sphere source prior to the intercomparison, but problems with a germanium sphere monitor detector made these results suspect. The data supplied to the participants correspond to a previous calibration of the sphere performed in September 1995.

Instead of calibrating the sphere at each level to be used to calibrate the ASTER SWIR, Mitsubishi selects a single level for calibration and uses a filter/germanium photodiode that is fixed to the sphere wall to set the radiance to levels required for the various ASTER SWIR bands. The sphere radiance is adjusted by changing the number of lamps that are illuminated and/or the position of a variable aperture between the 1-m sphere and one of two small satellite spheres that are mounted on the main sphere. Unlike the sphere operation at NEC, the lamps are always operated at the same current and voltage. The output of the sphere monitor is recorded by a computer and is displayed on a computer monitor, but no data are recorded in electronic format for future reference. The Mitsubishi calibration method requires that the sphere monitor be stable and linear with radiant flux and that the spectral shape of the sphere be independent of the lamp configuration or the position of the shutter between the satellite sphere and the main sphere.

Each day consisted of a series of measurements at one or two radiance levels. The typical measurement procedure was to turn on the ASTER SWIR sphere source to a given radiance level, determined by which lamps were on and the position of the shutter on the satellite sphere, and measure using the NRLM radiometers, the U of A shortwave infrared radiometer, and the GSFC monochromator. For some sphere levels, NRLM made measurements before and after GSFC and U of A. Shigeki Akagi of Mitsubishi adjusted the satellite sphere shutter or the illuminated lamps until the germanium monitor detector gave the correct reading. Since the sphere parameters were not recorded automatically, Carol Johnson recorded the output of the monitor detector during the measurements by the participants, and periodically recorded the currents, voltages, and operating hours on the lamps.

In this fashion, the sphere configuration for the ASTER SWIR Band 4 (at 1650 nm) was measured on the afternoon of 12 November and the morning of 13 November. ASTER SWIR Band 5 (at 2165 nm) was measured on the afternoon of 13 November, Band 6 (at 2205 nm) on the morning of 14 November, and Band 9 (at 2395 nm) on the afternoon of 14 November. Regardless of the sphere configuration, the U of A made measurements at all of the channels in the shortwave transfer radiometer (from 1244 nm to 2463 nm); GSFC made measurements from 1200 nm to 2400 nm; and NRLM used both transfer radiometers, which had center wavelengths at about 1600 nm and 2200 nm.

On the last measurement day, 15 November, the measurement procedure was varied so that two levels could be measured by all participants in the morning followed by equipment packing and transport in the afternoon. Because the only difference between the sphere configuration for Band 4 and Band 5 is the position of the shutter between the two spheres, the configuration was changed in the middle of the measurement procedure for each of the participants. As a result, Band 4 was measured by all participants at least three times, Band 5 was measured at least twice, and Bands 6 and 9 were measured at least once.

Finally, a special test was devised to examine the change of spectral shape of the sphere radiance as a function of the position of the shutter between the two spheres. The preliminary results from 12 and 13 November indicated that this test would be useful, and on the afternoon of 14 November, the U of A and NRLM measured the sphere for a particular lamp configuration and for three settings of the shutter (i.e., open, half-open, and 90% closed).

The preliminary results for the entire experiment at Mitsubishi indicate that the stability as measured at the beginning and end of a measurement sequence using the NRLM radiometers was about 0.5%. The reproducibility for turning the sphere off and back on to the same level was about 1%, as measured using the NRLM radiometers. When the participants' results are compared to the Mitsubishi calibration values, the scatter in the results is up to 10%.

NIST is coordinating the data analysis from this radiometric measurement comparison through its Statistical Engineering Division. The participants have submitted all raw data files, copies of log sheets, and descriptions of radiometers. It is expected that examination of the raw data will lead to uniform procedures for comparison of results acquired with instruments with different spectral, temporal, and spatial resolutions. Recommendations in calibration metrology will also be made where appropriate.

# Closing of the NASA Marshall DAAC and Reallocation of Data Sets

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The NASA Marshall Distributed Active Archive Center (DAAC) will be closing on March 31, 1997. This action is a result of NASA's reduced budget and the subsequent reallocation of resources within the rebaselined Mission to Planet Earth program. The data previously archived here will continue to be accessible at other EOSDIS DAACs, NOAA/NESDIS, the Lightning Imaging Sensor Science Computing Facility (LIS SCF), and the Global Hydrology Resource Center (GHRC), which is collocated with the Global Hydrology and Climate Center. A listing of these data sets with their current data center locations may be found at http://wwwdaac.msfc.nasa.gov (see data transition sub page). Note that the LIS SCF will also be the distributor of the TRMM LIS data products to be produced after the TRMM launch. All data sets will be accessible through EOSDIS, since all data providers are interoperable with EOSDIS.

**Marshall DAAC Version 0 Data Set Transition Tables**

| Data Set Groupings | New Archive |
|---|---|
| PRECIPITATION AND ATMOSPHERIC TEMPERATURES FROM SATELLITE:<br>MSU Limb93 Tropospheric and Stratospheric Temperatures 1979-1993 (Spencer & Griffin)<br>TOVS NOAA-NASA Pathfinder Path C1 (MSU) with Oceanic Precipitation<br>Geostationary Precipitation Index Monthly Rainfall (Arkin and Janowiak)<br>SSM/I Derived Ocean Monthly Rain Indices (Chang)<br>GPCC Global Precipitation (Rudolf et al.)<br>Monthly Mean Global Precipitation (Jaeger)<br>Surface and Ship Observation of Precipitation (Legates & Willmott)<br>SSM/I NOAA-NASA Pathfinder Precipitation (MSFC/DAAC) | GSFC DAAC |
| PRECIPITATION AND SURFACE WATER (NON-SATELLITE):<br>Amazon River Basin Precipitation (Dunne & DNAEE)<br>GISS Wetlands Database and Methane Emission (Matthews)<br>USGS Hydro-Climatic Data Network (Landwehr)<br>Hydroclimatology (Wallis, Lettenmaier, and Wood) | ORNL DAAC |
| ATMOSPHERIC WATER VAPOR:<br>NASA Water Vapor Project (Randel et al.)<br>SMMR Atmospheric Liquid Water (Prabhakara)<br>SMMR Atmospheric Water Vapor (Prabhakara) | LaRC DAAC |
| OVER OCEAN ATMOSPHERIC PRODUCTS:<br>SSM/I Geophysical Products from Satellites F8 & F10 (Wentz)<br>SSM/I NOAA-NASA Pathfinder Cloud Water and Water Vapor (MSFC/DAAC) | JPL DAAC |
| PASSIVE MICROWAVE RADIANCES FROM DMSP SATELLITES:<br>SSM/T-1 Level 1b Radiances (NESDIS)<br>SSM/T-2 Level 1b Radiances (NESDIS)<br>SSM/I Antenna Temperatures TDR (FNMOC) | NOAA/NCDC/SAA |
| SMMR & SSM/I HISTORICAL PASSIVE MICROWAVE:<br>SMMR Antenna Temperatures TAT (Gloerson et al.)<br>SMMR NOAA-NASA Pathfinder Brightness Temperatures (Njoku et al.)<br>SMMR Land and Ocean Parameters PARM-LO<br>SSM/I Antenna Temperatures for Satellites DMSP F8 & F10 (Wentz)<br>SSM/I NOAA-NASA Pathfinder Land Surface Products (MSFC DAAC) | NSIDC DAAC |
| CURRENT PASSIVE MICROWAVE PRODUCTS:<br>MSU Limb90 Tropospheric and Stratospheric Temperature Anomalies (Spencer & Christy)<br>AMPR Brightness Temperatures from CAMEX, TOGA-COARE, CaPE, and STORM-FEST field experiments (Hood & Spencer)<br>SSM/I Daily Cloud Liquid Water From DMSP F10 & F13<br>SSM/I Daily Integrated Water Vapor From DMSP F10 & F13<br>SSM/I Daily Ocean Wind Speed from DMSP F10 & F13<br>SSM/I Brightness Temperatures from DMSP F10, F11, & F13 | MSFC GHRC |
| LIGHTNING AND RELATED DATA SETS :<br>OTD Lightning Data Products (LIS SCF)<br>OLS Derived Lightning (NOAA/NGDC & LIS SCF)<br>Lightning Ground Strikes (GAI NLDN)<br>U.S. Lightning 15 Minute Total (GAI NLDN)<br>U.S. Lightning Daily Total (GAI NLDN)<br>U.S. 2 Km 15 Minute Reflectivity from NWS Radar (LIS SCF)<br>U.S. 2 Km Daily Rainfall Summary From NWS Radar (LIS SCF)<br>U.S. 8 Km 15 Minute Instantaneous Rainfall from NWS Radar (LIS SCF)<br>U.S. 8 Km Daily Rainfall Summary From NWS Radar (LIS SCF)<br>Geostationary Global Infrared Composite (NCEP AWC) | MSFC GHRC |

Many users of the Marshall DAAC have received Defense Meteorological

Satellite Program (DMSP) SSM/I, SSM/T1 and SSM/T2 data sets. After the closing of the Marshall DAAC, all the DMSP data sets named above may be obtained from either the NOAA Satellite Active Archive (http://www.saa.noaa.gov) or from the NOAA National Climatic Data Center (http://www.ncdc.noaa.gov). Thus the bottom line is that no data will be lost and access to all data sets will be continued.

The GHRC is the new name for the data and information system supporting the research activities within the Global Hydrology and Climate Center. The GHRC supports product generation, archiving, and distribution of research quality and operational data sets. The GHRC provides access to the Lightning Imaging Sensor data sets. The LIS SCF serves as the data production, archive, and distribution system for lightning data collected by the EOS lightning sensors (LIS and the Optical Transient Detector). Airborne and ground-based lightning calibration & validation data sets, as well as composite radar reflectivities and SSM/I brightness temperatures (used by the LIS science team for convective storm identification and for algorithm development and validation) will continue to be available for distribution from the LIS SCF through the GHRC.

The GHRC processes a variety of passive microwave data sets producing global tropospheric and stratospheric temperatures derived from the Microwave Sounding Unit, and global tropospheric water vapor derived from the Special Sensor Microwave Temperature Sounder (SSM/T2). In addition, aircraft passive microwave data collected during field experiments using the Advanced Microwave Precipitation Radiometer (AMPR) are available. These data sets currently reside with the Marshall DAAC but will be handed over to the GHRC in April 1997. You may search and order these data sets via the EOSDIS Version 0 IMS web page at http://harp.gsfc.nasa.gov/v0ims/. A future letter will provide you with more information about the GHRC. In the meantime you may learn more about the Global Hydrology and Climate Center and its research activities through our home page (http://wwwghcc.msfc.nasa.gov).

**Reallocation of V1 and Beyond Data Sets**

| Data Set Category | Reallocation Site |
|---|---|
| LIGHTNING IMAGING SENSOR PRODUCTS: | MSFC GHRC |
| LIS Level 0 | |
| LIS Derived Lightning Products | |
| TROPICAL RAINFALL MEASURING MISSION (TRMM) PRODUCT: | GSFC DAAC |
| TRMM Microwave Imager (TMI) | |
| TRMM Precipitation Radar (PR) | |
| TRMM Ground Validation Radar Data | |
| TRMM Combined instrument products | |
| ADVANCED MICROWAVE SCANNING RADIOMETER (AMSR) | |
| AMSR Brightness Temperatures | NSIDC DAAC |
| AMSR Snow and Ice Products | NSIDC DAAC |
| AMSR Land Products | EDC DAAC |
| AMSR Ocean Products | JPL DAAC |
| AMSR Precipitation/Water Vapor Products | GSFC DAAC |

| Acronym | Definition |
|---|---|
| AMPR | Advanced Microwave Precipitation Radiometer |
| AMSR | Advanced Microwave Scanning Radiometer |
| CAMEX | Convection and Moisture Experiments |
| CaPE | Convective Precipitation and Electrification Experiment |
| DAAC | Distributed Active Archive Center |
| DMSP | Defense Meteorological Satellite Program |
| DNAEE | Divisao Nacional de Aguas e Energia Eletrica (Brazil) |
| EDC | EROS Data Center |
| FNMOC | Fleet Numerical Meteorology and Oceanography Center |
| GAI | Global Atmospherics Inc. |
| GHRC | Global Hydrology Resource Center |
| GISS | Goddard Institute for Space Studies |
| GSFC | Goddard Space Flight Center |
| JPL | Jet Propulsion Laboratory |
| LIS | Lightning Imaging Sensor |
| MSFC | Marshall Space Flight Center |
| MSU | Microwave Sounding Unit |
| NCDC | National Climatic Data Center |
| NCEP AWC | National Center for Environmental Prediction Air Weather Center |
| NESDIS | National Environmental Satellite, Data, and Information Service |
| NGDC | National Geophysical Data Center |
| NLDN | National Lightning Detection Network |
| NSIDC | National Snow and Ice Data Center |
| NWS | National Weather Service |
| OLS | Operational Linescan System |
| OTD | Optical Transient Detector |
| PR | Precipitation Radar |
| SAA | Satellite Active Archive |
| SCF | Science Computing Facility |
| SSM/I | Special Sensor Microwave Imager |
| SMMR | Scanning Multichannel Microwave Radiometer |
| SSM/T | Special Sensor Microwave for Temperatures |
| TAT | Antenna Temperature Tape |
| TDR | Temperature Data Record (antenna temperatures) |
| TMI | TRMM Microwave Imager |
| TOGA-COARE | Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment |
| TRMM | Tropical Rainfall Measuring Mission |
| USGS | U.S. Geological Survey |

## LinkWinds new version, 2.2 is now available at http://linkwinds.jpl.nasa.gov/.

— **Lee Elson** (elson@magus.jpl.nasa.gov), Jet Propulsion Laboratory

For those of you not familiar with this free visualization package, here is a brief summary of its basic features:

LinkWinds applies a unique data-linking paradigm resulting in a system that functions much like a graphical spreadsheet. It is not only a powerful method for organizing large amounts of data for analysis, but provides a highly intuitive, easy-to-learn, easy-to-retain user interface on top of the traditional graphical user interface. The linking of data displays and controls for their manipulation provides great flexibility in rapidly exploring large masses of complex data to quickly detect trends, correlations, and anomalies. The system comprises a large and expanding suite of non-domain-specific applications and provides for the ingestion of a variety of database formats. Its many functions and services include

◊ 2-dimensional and 3-dimensional graphical displays of data.

◊ The ability to deal with very large data files.

◊ Interactive visual data subsetting either at the input or output.

◊ Supersetting to construct higher dimensionality data sets from sets of data files. This is useful for building time series from daily data accumulations.

◊ Simultaneous display and analysis of multiple data sets which may be totally unrelated.

◊ A unique and easy-to-use animation creation and display capability.

◊ Interactive color manipulation.

◊ A journal and macro capability allowing replay of an entire session or any portion thereof.

◊ Hard copy of graphical displays and text.

◊ A context-sensitive help system.

◊ Network support for collaborative data analysis with partners anywhere on the Internet, using virtually no bandwidth.

◊ In addition to archived data sets, LinkWinds has demonstrated an ability to ingest and display real-time data, which may be from spacecraft, laboratory experiments, or computer simulations.

The new version, 16 months in the making, has many new capabilities including the ability to run on Sun, HP, and Linux (PC) platforms in addition to the SGI family for which it was originally developed. Several new tools have been implemented including ValueView (displays numerical values), VolumeView (displays a volumetric rendering), enhanced hard-copy capabilities, and PointInterp which will draw an image from non-uniform sparse data such as that in the Upper Atmosphere Research Satellite Level 3 AT files. In addition to UARS files, LinkWinds can accept data in the following formats:

1) Raw binary data in signed and unsigned 1-, 2-, and 4-byte integers and 4- and 8-byte floating point.
2) The Hierarchical Data Format (HDF).
3) The Common Data Format (CDF).
4) NetCDF.
5) The Silicon Graphics, Inc. native RGB image format.
6) Data with Planetary Data System (PDS) headers.
7) The astrophysics Flexible Image Transport System (FITS).
8) ASCII text data.
9) Stratospheric Aerosol and Gas Experiment (SAGE) data format.

LinkWinds can act as an application spawned by Netscape or another Web browser. Thus, for example, one can download HDF files from the EOS DAACs and have them appear in LinkWinds as data objects.

Collaborative sessions or tutorials with anyone on the Internet are easily carried out using a low-bandwidth protocol.

For more information, visit our Web site (http://linkwinds.jpl.nasa.gov/) or send us e-mail (linkwind@twinky.jpl.nasa.gov).

# Virtually Hawaii: Earth Remote Sensing Data For Tourists

— **Peter Mouginis-Mark** (pmm@kahana.pgd.hawaii.edu), Hawaii Space Grant Consortium, University of Hawaii, Phone: (808) 956-3147, Fax: (808) 956-6322

A goal of NASA's MTPE program is to demonstrate the practical uses of Earth remote-sensing data sets to communities that do not normally see such information. The general public is one such group that sees a weather satellite image each night on television, but may be unaware of the wealth of additional information that is already available from spacecraft. As the NASA MTPE community prepares for missions such as EOS, Landsat-7, and Lewis and Clark, demonstrating to the population at large what can be seen by sensors working at different spatial resolutions and portions of the spectrum will be of great importance if the NASA MTPE effort is to be sustained.

One way to show the value of satellite observations is provided on the Internet's World Wide Web, which is fast becoming a common tool and/or entertainment for millions of people in the U.S. and around the world. Without recognizing the details of sensor design, instrument performance, or spacecraft orbits, the Web can show a great diversity of timely information to audiences that until recently did not have access to satellite images. To capitalize on this new medium, the Hawaii Space Grant Consortium (see the December 1996 issue of the MTPE Education Report for a description of Space Grant's goals) maintains a Web site called Virtually Hawaii (ref. #1) that purports to be directed towards tourism in Hawaii, but in fact offers much more to visitors in terms of technical descriptions of remote-sensing data sets and how to interpret them.

Virtually Hawaii is one of the Remote Sensing Database (RSD) programs funded as part of the NASA Cooperative Agreement Notice (CAN), "Public Use of Earth and Space Science Data Over the Internet." The RSD program is part of the Information Infrastructure Technology and Applications (IITA) component of the High Performance Computing and Communications (HPCC) initiative. Virtually Hawaii is run through the Hawaii Space Grant Consortium, which is one of 52 programs nationwide that NASA supports to promote space science education at the K-12, college, and graduate levels. Over 6,000 different computer sites access our pages every day (equivalent to ~2.2-million hits per month) so this is an excellent opportunity to showcase remote-sensing techniques as well as provide technical information on new scientific results.

Remote sensing data are used extensively in our presentations as the background to tourist attractions in Hawaii. A series of "Virtual Field Trips" each start with a satellite image of an island with points of general interest identified. Numerous multispectral and radar aircraft images are also presented to explain specific aspects of ecology, geology, and coastal processes. Our "Image Navigator" provides a direct comparison between Space Shuttle photography, Landsat, and Shuttle radar (SIR-C) images of the same geographic areas. Further technical information is also provided via a tutorial on the oceanographic applications of satellite data, and the current remote sensing methods for studying active volcanoes (a big attraction for tourists planning to come to Hawaii!).

As the visitor becomes more familiar with seeing satellite images, there are also more-detailed segments of our presentation that focus on the information content of remote-sensing data. We feature a tutorial on multispectral imaging (ref. #2) as well as an "Interactive Spectral Imager" (ref. #3) where people can select which visible and infrared wavelengths they wish to use to view downtown Honolulu. In the near future, we also plan to provide supplemental analyses of live video camera and weather satellite data (ref. #4) to help people understand cloud patterns, ocean wave spectra, and solar radiation.

Virtually Hawaii has proven to be particularly popular both to individuals planning a visit to Hawaii, and to researchers searching for technical information on remote sensing. More significantly, we have also received a diverse range of questions from local businesses, school teachers, and state offices. Given that these groups are rarely present at scientific conferences when mission results are presented, it is pleasing to see that the Web is acting to demonstrate the value of remote sensing. In several cases, these groups suggest practical uses for the data or have developed commercial ideas around our material demonstrating the applications aspect of the sensor data. While our presentation is focused on Hawaii, it is likely that several of the techniques could be equally well applied to other states in the U.S. or to other parts of the world, thereby increasing public awareness of satellite data at just the right time to enable them to see and, in some cases, utilize the next generation of data sets from spacecraft such as EOS.

URL References:

1) http://hawaii.ivv.nasa.gov/space/hawaii/index_mirror.html
2) http://hawaii.ivv.nasa.gov/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral. 1.html
3) http://hawaii.ivv.nasa.gov/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral. 4.html
4) http://satftp.soest.hawaii.edu/satlab/index.html#fromvirtual

## *Satellite Remote Sensing Measurement Accuracy, Variability, and Validation Studies*

NRA-97-MTPE-03

NASA announces the solicitation of proposals for scientific investigations and activities in support of NASA's Mission to Planet Earth (MTPE) Program that will quantify and/or improve the accuracy of geophysical measurements derived from current satellite observations and from the initial Earth Observing System (EOS) satellite sensors.

Two types of proposals are requested by this announcement. (Type 1) NASA's "Global Data Integration and Validation Program," an MTPE Research and Analysis Program, is requesting proposals to determine the geophysical measurement accuracies of data from current or historical research and operational satellite sensors; to conduct studies of the time and space variability of the derived geophysical parameters, including uncertainties; and to analyze the impacts of these uncertainties on subsequent interpretations and applications. (Type 2) NASA's EOS Program requests proposals for investigations and activities that will enhance, supplement, and/or complement activities planned by the EOS Instrument and Interdisciplinary Science Teams to characterize and validate the accuracy of remotely-sensed geophysical parameters derived by the Instrument Science Teams from measurements by EOS satellite sensors in the AM-1 time frame.

This solicitation is available electronically at the MTPE home page: http://www.hq.nasa.gov/office/mtpe/ under "MTPE Research Announcements," or via anonymous ftp at ftp.hq.nasa.gov/pub/mtpe. Paper copies are available to those who do not have access to the Internet by calling (202) 358-3552 and leaving a voice mail message with your full name and address including zip code, and your telephone number including area code.

Questions regarding this NRA can be addressed to NASA Headquarters, Code YS, Washington, DC 20546, Attn.: Dr. James Dodge, telephone (202) 358-0763, Fax (202) 358-2770, e-mail: jdodge@hq.nasa.gov. For questions regarding the EOS Type 2 proposal, please contact Dr. David Starr, telephone (301) 286-9129, e-mail: starr@climate.gsfc.nasa.gov.

Letters of intent are due April 17, 1997; proposals are due May 16, 1997.

## Science Calendar

| | |
|---|---|
| April 11-12 | EOS-IDS Atlanta Land Use/Climate Change Project Team Meeting, GHCC, Huntsville, AL. Contact Dale Quattrochi, tel. (205) 922-5887, e-mail: dale.quattrochi@msfc.nasa.gov. |
| April 14-17 | 2nd U.S.-Japan Earth Remote Sensing Conference, Sheraton Orchid at Mauna Lani, Kohala, Hawaii, Contact Peter Mouginis-Mark, tel. (808) 956-3147, e-mail: pmm@kahana.pgd.hawaii.edu. |
| April 15-17 | Landsat-7 Science Team Meeting, Lockheed Martin Missiles and Space Facility, Valley Forge, PA. Contact Darrel Williams, tel. (301) 286-8860, e-mail: darrel.williams@gsfc.nasa.gov. |
| April 16-18 | CERES Science Team Meeting, NASA/Langley Research Center. Contact Gary Gibson, e-mail: g.g.gibson@larc.nasa.gov. |
| April 22-24 | Land Processes DAAC Science Advisory Panel Meeting, USGS EROS Data Center, Sioux Falls. Contact Bryan Bailey, tel. (605) 594-6161, e-mail: gbbailey@edcmail.cr.usgs.gov. |
| May 6-8 | First JPL Workshop on Remote Sensing of Land Surface Emissivity, Pasadena, CA. Contact Anne Kahle, e-mail: anne@aster.jpl.nasa.gov or Alan Gillespie, e-mail: alan@oz.geology.washington.edu. |
| May 13-16 | MODIS Science Team Meeting, Holiday Inn, College Park, MD. Contact: Belinda Kalinin, (301) 286-9609, e-mail: belinda.m.kalinin.1@gsfc.nasa.gov. |
| May 20-23 | ASTER Science Team Meeting, Sioux Falls, SD. Contact Anne Kahle, e-mail: anne@aster.jpl.nasa.gov, or H. Tsu, e-mail: tsu@ersdac.or.jp. |

## Global Change Calendar

| | |
|---|---|
| May 28-29 | Tenth Annual Towson State University GIS Conference (TSUGIS '97). Contact Jay Morgan, Department of Geography and Environmental Planning, Towson State University, Baltimore, MD 21204-7097, tel. (410) 830-2964, Fax: (410) 830-3888, e-mail: e7g4mor@toe.towson.edu. |
| June 12-13 | The International Climate Change Conference and Technologies Exhibition, Baltimore, MD. Call for Papers. Contact Exhibition office, tel. (301) 695-3762, Fax: (301) 295-0175. |
| July 1-9 | IAMAS/IAPSO Joint Assemblies, Earth, Ocean, Atmosphere: Forces of Change. Melbourne, Australia. e-mail: mscarlett@peg.apc.org, WWW: http://www.dar.csiro.au/pub/events/assemblies. |
| July 7-10 | Third International Airborne Remote Sensing Conference, Copenhagen, Denmark. Contact ERIM/Airborne Conference, P.O. Box 134001, Ann Arbor, MI 48113-4001. tel. (313) 994-1200, ext. 3234; Fax: (313) 994-5123; e-mail: wallman@erim.org. WWW: http://www.erim.org/CONF/conf.html. |
| July 21-23 | 2nd International Symposium on "Reducing the Cost of Spacecraft Ground Systems and Operations," Keble College, Oxford University, UK. Abstracts of 5-10 pages due January 15. Contact Richard Holdaway, Rutherford Appleton Laboratory, tel. +44(0) 1235 445527, Fax: +44(0) 1235 445848, e-mail: r.holdaway@rl.ac.uk. |
| August 4-8 | 1997 International Geoscience and Remote Sensing Symposium, Singapore. For more information contact IEEE/GRSS, 2610 Lakeway Drive, Seabrook, TX 77586. e-mail: tstein@phoenix.net, tel. (713) 291-9222; Fax: (713) 291-9224. |
| September 8-12 | WMO Fifth International Carbon Dioxide Conference, Cairns, Queensland, Australia. e-mail: 97CO2@dar.csiro.au. WWW: http://www.dar.csiro.au/pub/events/co2_conf/index.html. |
| September 22-26 | Conference on Sensor, Systems and Next Generation Satellites III. Call for papers. Contact Steve Neeck, tel. (301) 286-3017, e-mail: steve.neeck@gsfc.nasa.gov. |
| October 13-16 | International Conference on Earth Observation & Environmental Information (EOEI' 97), Alexandria, Egypt. Call for Papers. Contact Bashir Saleh, tel. (203) 5602578, 5601785, Fax (203) 5602915, email: ruaafeng@rusys.EG.net, or Nader Nada, tel. (730) 993-1626, Fax (703) 993-3729, email nnada@osf1.gmu.edu. Internet: http://www.frcu.eun.eg/ www/conference/aast.html, or http://www.ceosr.gmu.edu/news.html. |

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